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ORIGINAL ARTICLES.

The Mudstreams ("Lahars") of Gunong Keloet in Java.

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MAP REFERENCE: Verbeek et Fennema, Carte Géologique de Java et Madoura, 1896, C. VIII. See also Vulkanologische Mededeelingen; Dienst v. h. Mijnwezen in Ned. O. Indie, No. 2, 1921.

SOME time ago I was asked, in connection with a question regarding the Dwyka conglomerate, to say if any of the volcanic deposits of Java in any way resemble a glacial deposit. As I was in Java from 12th May to 6th June as a Member of the Fourth Pacific Science Congress, and travelled from Batavia to Soerabaya via Buitenzorg, Bandoeng, Garoet, Koeningan, Loh Ulu, Jocja, Kediri, and the Tengger Mountains, as well as going to Krakatau, I had a good opportunity of replying to the question, but it must be understood that this note is not intended as a contribution to literature on the Dwyka conglomerate, which I have never seen, but purely as an answer to the query "are there any volcanic deposits in Java resembling glacial deposits?" The reply briefly is that such deposits do exist, namely the "mudstream-deposits" of Gunong Keloet, near Kediri.

Gunong Keloet is an active volcano, only 1,731 metres high, with an evil reputation, having brought disaster to the surrounding country by repeated eruptions in historical times. Widespread destruction and loss of human life have been caused by the ejection of a crater-lake when an eruption takes place, resulting in "mudstreams" that rush down the side of the volcano along old drainage channels, filling and overflowing them, covering the ground with mud, stones, and boulders that are transported long distances by the flow of water thickened by the mud and stones. The last eruption took place in 1919 on the night of 19th–20th May. The following account of the eruption is taken from a pamphlet written for Members of the Congress by Dr. Ch. E. Stehn, Chief of the Volcanological Survey, and Dr. J. H. Coert, who conducted a party, including myself, to see the mudstream-deposits. It is estimated that thirty million cubic metres of water were thrown out of the crater, the first water to reach the plain being cold, but the later flow being hot.

"Immediately after this the contents of the crater-pipe were ejected in the form of small pieces as well as *débris* from the inside of the crater. Scorching clouds came down. The normal eruptive action followed, explosion-like escaping of gases, more or less loaded with ash. Gradually the action decreased. It changed to the Solfatara-stage." Later, rain and spring-water reappeared in the crater and eventually refilled it.

The greatest distance covered by the mudstreams on this occasion was 38·25 km. The breadth of country traversed by the mudstreams that passed through the town Blitar and the land to the north-west was 20·25 km. Some individual flows spread out laterally over more than 4 km. It was estimated that during the eruption the rate of flow between an estate near the crater and Blitar was 16 km. in 15 minutes, the difference in height being 270 m. In Blitar the mudstream was 1·5 m. to 2·5 m. high. Within 45 minutes the flow had ceased. Five thousand one hundred and ten human lives were lost, 104 villages totally or partially destroyed, and 131·2 square kilometres covered by the mudstream deposits.

One side of the crater has now been pierced by tunnels in the hope that this means of drainage will prevent any future disaster.

I saw the deposits left by the mudstreams near Blitar and also between Kediri and the foot of the pass over to Malang. The deposits had been modified, of course, by surface erosion, and the result was that numbers of large boulders, in groups or isolated, lay irregularly over a wide area, partly cultivated since the flow took place, but partly too stony to grow crops. In one spot, where the mudstream had filled a narrow valley, subsequent erosion had left large boulders high up on the slopes, where, from a distance, they looked like erratics. In two of these stone-fields I searched for scratches and polished surfaces. In both stone-fields I found scratches on boulders and on one large boulder a polished and scratched surface. These were pointed out at the time to fellow geologists, who agreed on the similarity to glacial markings, though the latter are more distinct. One geologist from New Zealand was particularly interested in these mudstream-deposits, because there, he told me, he had opposed the theory that similar deposits are of glacial origin, and he felt that these Gunong Keloet deposits completely justified his opposition.

Excellent photographs of these deposits are published in No. 2 of the Vulkanologische Mededeelingen (see above); Photos 31 (p. 32) to 37. Photo 36 is particularly striking, showing a boulder about 10 ft. high and as much in breadth and even more in length.

Deposits such as these, however, must be mainly, if not entirely, composed of volcanic material. The only exception can be material picked up by the mudstreams during their flow. In the Keloet deposits I cannot be sure of having seen any non-volcanic material and Verbeek and Fennema mapped the whole area over which the mudstreams flowed as volcanic.

Contributions to the Geology of Cyprus.

By F. R. Cowper Reed, Sc.D., F.G.S.

THE general features of the geology of Cyprus have been established by the work of Gaudry and of Bellamy and Jukes-Browne (1),[1] (2); while the later researches of Professors Cullis and Edge (3) have added much to our knowledge. But in every case it has been recognized that many questions were left unsettled and many details remained to be filled in. In this connection the importance of the geological work which has been done during recent years on the neighbouring coasts of Asia Minor and Syria has been somewhat overlooked, though in view of the close tectonic relations between the mainland and Cyprus it deserves particular attention. The structure of the northern range of mountains in Cyprus, the age and relations of the igneous rocks and the correlation of the Tertiary beds with those in the Mediterranean area were three of the main questions which the author set himself to study during a recent visit of nearly two months to the island. But it was soon recognized that a systematic geological survey was necessary for their complete solution, the structure being much less simple than has been previously believed. The following field-notes are therefore only preliminary and the conclusions provisional.

The succession and characters of the formations which were given as follows by Bellamy and Jukes-Browne in 1905 have been accepted with minor qualifications by Cullis and Edge and are an invaluable foundation on which to build a more detailed classification.

Pleistocene	Alluvial deposits, sandy limestones, sands, and conglomerates.	
Pliocene	Newer Older	Shelly limestones with calcareous sands and sandstones.
	Break (intrusion of igneous rocks).	
Idalian	Newer (Miocene)	White shelly limestones, white chalky limestones, and marly chalks with layers of flint.
	Older (Oligocene ?)	Grey and yellowish marls with beds of gypsum.
Kythrean	Upper Eocene or Oligocene	Grey felspathic sandstones and sandy shales.
Trypanian	Eocene (? Lapithos Beds)	Greenish shales with hornstone bands.
	Cretaceous ?	Grey limestones and dolomites, white and pink marbles, both massive and laminated.

It should be mentioned that Frech in his geological map (7, t. xxi) of Anatolia and the eastern Mediterranean marks in a large mass of Palaeozoic rocks occupying the Troodos mountain area in Cyprus, but there is no evidence existing of which I am aware that any of the rocks occurring there are of Palaeozoic age. He also colours the western end of the Kyrenia Range (west of Lefkonico) as composed of Cretaceous and Eocene beds, though the rest of the island is left uncoloured. It has been stated by Sagui (5) that west and south of Troodos there is a horizon of crystalline schists " probably of Azoic age ", but the present author has not met with them in his rapid traverses of that area.

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[1] Numbers in parentheses relate to references at the end of the paper.

(1) STRUCTURE OF THE NORTHERN RANGE.

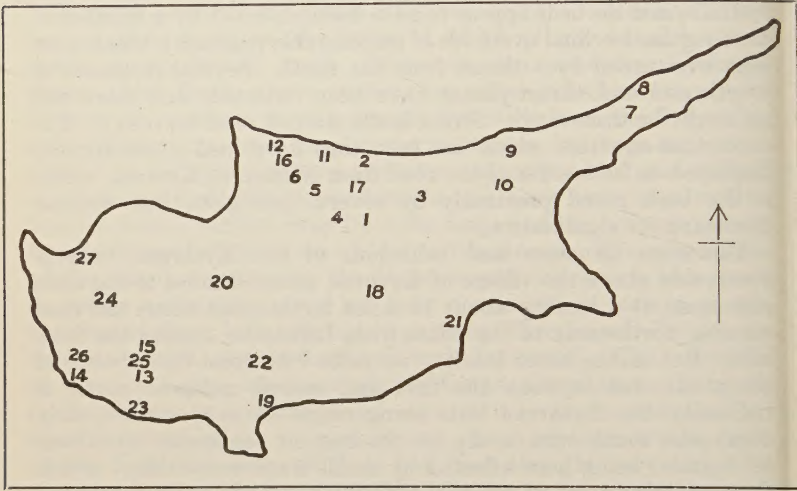
It has been stated by Cullis and Edge (3) that the Trypanian beds in the northern or Kyrenia Range are highly inclined and folded into a sharp anticline, the limbs of which plunge beneath newer strata to north and south. Moreover, the overlying Kythrean Series which flanks the mountains on either side has been stated to have its members dipping steeply outwards from the Trypanian axis, although near the base of the mountains the beds have been noticed to be highly inclined and often strongly folded and faulted or even inverted, but these disturbances have been observed to become weaker further away from the range and the beds ultimately to pass below the later cover of Idalian limestones. The central area of the island constituting the Mesaoria and forming a wide level or gently undulating plain has been considered to form a simple syncline of these beds overlaid in parts by Pliocene and Pleistocene deposits which are undisturbed and horizontal. The southern or Troodos Range, which completely bounds the plain on the south in the western part of the island—though it is also represented by some detached hills in the eastern end—has a separate development of the Kythrean beds which it has been thought may form the southern limb of the main syncline, the trough of which has been broken through by the intrusive rocks of the Troodos, but it has also been suggested that they may have been deposited in a separate basin. The opinion expressed by Blanckenhorn (6, p. 125), and by Frech (7, p. 175), that the Troodos consists of older rocks which have formed a horst against which the beds have been thrust by pressure from the north, or that it is a faulted inlier, so that it corresponds with the Kurdish Mountains (6, p. 128) and Djebel Koser (Casius) (6, p. 114) of the mainland, does not appear to have been sufficiently considered, but it has much to recommend it, bearing in mind the correspondence of the tectonic relations and of the formations in these two areas. We shall have occasion to refer to this matter subsequently.

In the first place we have found that the behaviour of the Kythrean beds on the south of the Northern Range in Cyprus and the structure of the Trypanian axis is not as simple as supposed : for the occurrence of complicated overfolding and thrust-planes have been observed in several traverses. The Kythrean Series on the south side of these mountains forms a continuous regular range of low foothills having a fairly uniform elevation (well seen in evening light from Nicosia) and a peculiar broken and irregular hummocky surface mostly barren or uncultivated. The beds in these foothills along their whole length are found to dip *northwards* (with few exceptions) at high angles towards the axis of the range, so as to form a succession of parallel bands running east and west, the harder layers weathering out as narrow prominent step-like or wall-like rocky ridges, the outcrops being traceable continuously for miles across country owing to the nature of the ground. In places the beds are vertical, and the dip is rarely at low angles, while it is only where secondary undulations occur that the dip is to the south. The localities at which this structure is displayed are numerous along the whole range of the foothills, and the beds appear to have been repeated by a number of close regular isoclinal overfolds of considerable regularity which have been overturned by a thrust from the north. Several instances of overthrusts and thrust-planes have been detected, and more will no doubt be discovered. Strike-faults do not seem to occur. The concertina-structure which has been thus developed is remarkably displayed on both sides of the road from Nicosia to Kyrenia, where it has been noted previously by several geologists, but without discussing its significance.

The same structure and behaviour of the Kythrean beds is observable above the village of Kythrea, some 10 miles to the east, and again at a locality about 15 miles further east where the road running northwards to the coast from Lefkoniko crosses the foothills. But in the latter locality we meet with local disturbance of the strike, for between the first and second milepost north of Lefkoniko the Kythrean beds swing round so as to strike nearly north and south with a dip to the east or south-east at about 45 degrees, being here affected by small transverse folds ; nearer the mountains north of milepost 5 on this route the strike reassumes its normal east to west direction, and the dip becomes steep and to the north. Between the 7th and 8th milepost a patch of Kythrean beds is folded into the Trypanian limestones, and in the road-cuttings on the Pass itself several small overfolds to the south and thrust-planes are distinctly visible, while crush-breccias likewise occur. On a bare hillside some miles east of this road from Lefkoniko a much larger overfolded syncline is seen, and still further east, near Agios Jakovos, a thick mass of Trypanian limestone, breaking off in a vertical cliff and capping a high advanced ridge, rests on the truncated edges of steeply inclined Kythrean beds dipping north at about 75 degrees, the junction apparently being a gently inclined thrust-plane.

Travelling in the opposite direction now to the west of Nicosia the Kythrean beds 2 miles west of Yerolakko are gently folded, but between Skilloura and Kondemenos on the south side of the road to Myrtou they dip south at 30–45 degrees, while on the north side of the same road the dip is at 60–75 degrees, but here we are distant several miles from the foot of the mountains. Further west, 3 miles beyond Asomatos on the same road, the dip is seen to have changed and to be to the north at 45 degrees, for we are here approaching the foot of the mountains. Further exploration is required in this region, for the author was much hindered by bad weather.

The whole series of Kythrean beds forming the foothills on the south side of the Kyrenia Range is thus seen to have been affected by mountain-building movements, the effects of which die out at a distance from the axis where the beds pass below the later calcareous deposits of Idalian age. It is not at present clear to what extent the Idalian beds on this side were affected by the same movements or if these strata have been removed by denudation from the foothills, while in the plain the relations are obscured by the extensive cover of Pliocene deposits and later accumulations.



Outline Map of Cyprus.

Reference Numbers on Outline Map.

1.	Nicosia.	15.	Kelokethara.
2.	Kyrenia.	16.	Panagra Gorge.
3.	Kythrea.	17.	Kyrenia Pass (summit).
4.	Yerolakko.	18.	Alambra.
5.	Skilloura.	19.	Limassol.
6.	Asomatos.	20.	Evrykou.
7.	Agios Andronikos.	21.	Larnaca.
8.	Yialoussa.	22.	Yerasa.
9.	Akanthou.	23.	Petra tou Roumiou.
10.	Lefkoniko.	24.	Simou.
11.	Lapithos.	25.	Stavrokono.
12.	Orga.	26.	Emba.
13.	Mamonia.	27.	Polis.
14.	Ktima (Paphos).		

Turning to the north side of the Kyrenia Range we find that the

Kythrean beds with few exceptions dip away from its axis instead of towards it, and usually lie at lower angles than on the other side.

Thus near Agios Andronicos on the road to Yialoussa, near the east end of the range the beds dip north at about 60 degrees, and beyond Yialoussa in like manner at high angles seawards. Below Akanthou village north of Lefkoniko they dip at 30–45 degrees to the north with thick coarse conglomerates at their base, and in the gorge below the road down to Kyrenia from Nicosia near the 13th milepost the basal conglomerates are vertical, while near Mr. Campbell's house (1,100 feet above sea-level) similar beds dip north at lower angles and are here affected by several broad low folds. In the road-cutting near the 14th milepost from Nicosia on this Pass the beds gently undulate, but mostly dip north at about 45 degrees. The same behaviour of these beds is noticeable in the gorge and along the road below Lapithos, a village about 8 miles west of Kyrenia. But on the slopes of the hill below Orga on Georgios Bay, some 6–8 miles further west, near the end of the range, the strike of the beds swings round and the dip becomes easterly at about 30 degrees.

Transverse faulting affecting the whole breadth of the Northern Range has also occurred, and one such fault seems to cut obliquely across it along the line of the Kyrenia Pass north of Nicosia, apparently shifting the rocks northward on the west side. Further faulting and thrust-planes of various degrees and extent can be observed elsewhere.

From the foregoing observations in the field, which indicate that the Northern Range of Cyprus owes its structure to a thrust from the north and shows features closely similar to those described by various observers on the opposite mainland, we are able to support strongly the theory that it is a continuation of the Amanus Mountains—the marginal zone of the Taurus system—a view which Suess, Blanckenhorn (6), Kober (8), and Frech (4), (7), have maintained. But we have not yet discovered the occurrence of Palaeozoic and Jurassic rocks in the mountain complex, the Trypanian rocks being generally regarded as Cretaceous, though no fossils have been found in them ; there is, however, such a diversity of lithological types amongst the limestones that it is quite probable that beds of more than one period have been included under this name. Kober accepts Gaudry's view that they are Cretaceous. Frech (4), (7), suggests that the unfossiliferous limestones in the Amanus Range, which in places (Dül dül dagh) have been thrown into overturned folds (such as can be seen locally in the Trypanian axial beds of the Kyrenia Range), are probably of Lower Carboniferous age similar to those which occur in the Taurus Range to the north, for they have a Palaeozoic appearance, and it is possible that such may be found in Cyprus.

The age of the Kythrean beds themselves awaits definite fossil evidence, for only a few foraminifera have previously been found, though the author has discovered a layer full of fucoid markings and of undoubted pteropods on the road to Kyrenia, such as Kober (8) mentions in the Flysch of the mainland, and the latter author refers the Cyprian beds to the Oligocene rather than the Eocene. There is a sharp discordance, according to Kober, between the older and newer Tertiaries, but the relations between the Lapithos and Kythrean beds is uncertain, and the greenish marls at the top of the Kythrean are said by Bellamy and others to pass up conformably into the Idalian. On these points further evidence is much required.

Though the chief period of mountain-building took place before the Miocene, according to Kober (8), Frech recognizes three distinct periods of folding in the Amanus Range: (1) at the close of the Palaeozoic or in the Mesozoic; (2) in pre-Miocene, probably Oligocene times (the Antitauric folding); and (3) the Tauric folding at the beginning of the Pliocene (Pontian stage) before the transgression of the sea of the 3rd Mediterranean stage. The intrusion of serpentine and other igneous rocks into the Cretaceous and Lower Eocene took place some time during the Upper Eocene, according to Frech (7). This is important in its bearing on the age of the igneous rocks in Cyprus. But it seems that there was more than one period of igneous activity in Cyprus, though probably all were pre-Miocene. The great diversity of types amongst the basic and ultrabasic igneous rocks in Cyprus is noticeable, and so is the great rarity of acid rocks.

In view of the many points of similarity between Northern Syria and Cyprus, we are tempted to suggest the probability that the central plain, the Mesaoria, of Cyprus corresponds in some degree with the Ghab—the plain of the Kara Su, which separates the Amanus Range from the Kurdish Mountains—in both cases the plain forming an intermediate sunken area. There is also a certain resemblance in the general relations and structure of the Himalayas, Siwaliks and Gangetic Plain. The association of serpentine masses with Eocene limestones in the Amanus Range, which show dynamic but not contact-metamorphism is paralleled by the relations of the supposed Lapithos beds and igneous rocks of the Kyrenia Range as exhibited in the Panagra gorge (described below). This is another feature in common between the two areas.

The possibility of the Troodos being a horst like the Kurdish Mountains has been already mentioned, but there is no evidence of anything in Cyprus corresponding to the Syrian plateau, which on the mainland lies south of the "Afrin line" (9).

With regard to the occurrence of Kythrean beds on the south side of the Troodos Range, the observations of Bellamy and Jukes-Browne have been confirmed by Cullis and Edge, several outcrops of these beds being recognized in this region, but the latter authors were not able to discover their occurrence in certain localities on the north flank of the Troodos, as described by the earlier investigators.

The present author was unable to visit these places. The character of the beds on the south side was mostly found to differ considerably in lithological features from those in the Kyrenia Range, although on the road to Mamonia north of Kouklia there are sandstones of true Kythrean character in thick beds dipping W.S.W. at 75 degrees, and overlying reddish shales. Similar sandstones occur close to Ktima (Paphos). But the beds which are intimately associated with the igneous rocks in this neighbourhood, and have been mapped as Kythrean are of a different type. For instance, about 50 yards beyond the branch road from Mamonia to Kelokethara an interesting section shows intensely folded and crumpled dark red sandstones in thin beds, pebbly massive sandstones, tough red shales which break up into small cubical fragments, and white flinty bands (hornstones) with silicified marls caught up amongst igneous rocks (serpentines) with extensive deposits of *terra umbra* and *terra verte*. Similar rocks are exposed on the road between Emba and Tala north of Ktima, as described below in connection with the igneous rocks of these localities. Further work is necessary to elucidate the age and relations of these beds. But we may call attention to their resemblance to those of the " shale and hornstone formation " of the inner zone of the Taurus and Hellenides described by Kober (8, p. 415), which are likewise accompanied by great eruptive masses of serpentine, etc.

(2) RELATIONS OF THE IGNEOUS ROCKS.

Although a great variety of intrusive and other igneous rocks have been recorded from time to time in Cyprus and their petrological characters described (11) (12), there is no general agreement as to their relations to one another or to the Tertiary sedimentary beds with which they are associated. Cullis and Edge (3), however, have recognized three main types of igneous rocks—the pillow-lavas, the serpentines, and the diabase of the Troodos, and their work in connection with the cupriferous deposits of the island leads them to conclude that the volcanic rocks comprising the pillow-lavas are probably not intrusive but are submarine flows, for they have not produced any thermal metamorphism in the contiguous sediments. The serpentines and related rocks are believed by these authors to invade the lavas in places, but the diabase is thought to be probably a good deal older than either of the other types. Kober (8) considers the andesitic and trachytic lavas in Cyprus to be of Oligocene age, while the serpentines, etc., on the mainland as found in the Kurdish Mountains are regarded by Blanckenhorn, Frech, and others as constituting earlier intrusions which took place principally towards the end of the Cretaceous or beginning of the Eocene, though they lasted on till the Upper Eocene. The Eocene limestones associated with the serpentines in Syria and Asia Minor show dynamic but not contact-metamorphism, as evidenced by their shattered, crushed, and fissile condition, just as we find to be the case in Cyprus. Finkh's (10) description of the occurrences and petrological characters of the serpentines, etc., in North Syria show that they correspond closely with those in Cyprus.

The present author has not attempted to make an examination of the complex Troodos massif, or of any of the igneous rocks from a petrological standpoint. Bergeat (11), Zdarsky (12), and others have studied and described many of them, but the field observations are mostly disconnected.

The exposures which have been visited were selected in order to obtain evidence as to the relations of the igneous to the sedimentary rocks, and they have yielded several facts of importance, though they introduce new difficulties of interpretation.

Beginning at the west end of the Kyrenia Range, there is in the Panagra gorge north of Myrtou an interesting contact between limestones and igneous rocks. The limestones are white and marly containing tabular and nodular flints and are much crushed and shattered near the junction. They rest against and upon a mass of igneous rock (serpentine), which is itself brecciated and shattered along its line of contact. In one place soft pinkish much crushed and fissile calcareous shales or shaly limestones are traceable for several yards in actual contact with the igneous mass. But there is no evidence of thermal metamorphic changes in the sedimentary rocks and the facts indicate that both the sedimentary and igneous rocks have been mutually affected by intense tectonic movements which took place after the limestones had been deposited on the older igneous foundation.

Near the summit of the Kyrenia Pass, 11 miles from Nicosia, there is a very similar exposure of identical beds, but the relations are better exhibited, for patches and sub-angular fragments of the associated igneous rock are included in the crushed and shattered limestones which are shaly or fissile in character, pinkish to greenish in colour, and traversed by small thrust-planes and crush-zones or veined by calcite. Occasional rounded pebbles of diabase are also contained in the limestones, which is a particularly suggestive fact. A large exposure of the solid igneous rock from which the fragments are derived is seen in the road-cutting. It is obvious that the igneous rock here is not intrusive, and the limestones are identical in character with those at the Panagra gorge. The massive compact uncrushed limestones (Trypanian) outcropping on the hillsides just before reaching the summit of the Pass have a completely different character to these crushed chalky limestones which may belong to the Idalian or more probably to the Lapithos formation, for the typical Idalian in the vicinity is separated from them by a wide outcrop of Kythrean sandstones.

The cliffs below Orga at the west end of the Northern Range show most interesting and complicated sections, the crushed limestones which occur there being caught up, folded and faulted in with the igneous rocks. Irregular strips and masses of the limestones are involved with much shattered and brecciated igneous rocks, and all the beds are folded and frequently overturned and traversed by small thrust-planes. Thin bands of coarse grit of unusual character are folded in with the limestones. But there is no clear evidence of the intrusion of the igneous rock subsequent to the deposition of the calcareous sediments. Bellamy (2, p. 16) has given a section on this coast at a place which he calls "Skasmata Peak", in which the contact of the Lapithos beds and the igneous rocks is illustrated, but the present author has not been able to identify the locality.

In the case of the exposure at Kythrea Spring, near Nicosia, there are similar crushed chalky limestones faulted and forced up against dark bituminous limestones (Trypanian), and an igneous mass is marked in here on Bellamy's map. But this complicated area requires much more study and exploration, which the present author was prevented from carrying out.

Turning to the occurrences on the south side of the Mesaoria Plain, but on the north of the Troodos Mountains, we find in the narrow pass near Alambra, on the road to Limassol, beds of undoubted typical Idalian chalk and marl containing flints and resting directly on the pillow-lavas (andesites) which are usually vesicular at their contact. The calcareous beds are silicified, and have become very tough and horny near the junction, breaking with a sub-conchoidal fracture; in places they are completely replaced by silica. Soft pinkish shales also occur on the lower slopes of the hill, but their relations are rather obscure. The lavas themselves are traversed by veins of jasper and other siliceous material, as may be well seen in a small rocky knoll on the east side of the road. Solfataric action subsequent to the extrusion of the lavas and deposition of the calcareous sediments is believed to be indicated by these features, as Cullis and Edge (3, p. 9) have suggested. Bellamy (2, p. 34) gave a diagrammatic section of this occurrence at Alambra.

At Koronia Hill on the Evrykou road, just before the 26th milepost from Nicosia, the massive dolomitic limestone known as the Koronia Limestone (in places full of small gastropods and *Globigerina* tests) is strongly silicified near its base and rests unconformably on the pillow-lavas, a calcareous conglomerate 3–4 feet thick containing fragments of these and of other igneous rocks intervening between the two formations. Conspicuous vertical dykes here penetrate the andesite and stand up as walls which cross the neighbouring ravines.

On the east side of the road from Nicosia to Larnaca near the 9th milepost there is a considerable group of small low rounded hills composed of purple- and green-veined igneous rocks, locally amygdaloidal, directly overlaid by Idalian chalky beds dipping at 30 degrees to the north, and these are not altered or silicified in the least; on the south side of these hills the same chalky beds dip to the south. We have here again an undoubted occurrence of calcareous beds deposited on a pre-existing igneous foundation.

On the south side of the Troodos Range we find near Yerasa the Idalian beds resting with a basal conglomerate on pillow-lavas which are much weathered and broken. The conglomerate contains rounded and subangular pebbles of the lava itself, and is not a crush-breccia, while the marls and chalk of the Idalian do not show any signs of alteration.

On the south coast at Petra tou Roumiou, on the coast road between Limassol and Paphos, two narrow tongues of igneous rocks (chiefly serpentine) extend to the shore; the rock is fresh and amygdaloidal in places, and includes patches of the massive limestones which it pierces and marmorizes. Much *terra umbra* is associated with it. The beds are much disturbed and folded, and form conspicuous large sea-stacks or isolated rocks on the foreshore. We have a genuine intrusion here producing marked alteration in the limestones which, however, are probably of Trypanian age, for they do not appear to possess the characters of any of the Idalian beds, and consist in part of a beautiful fine-grained marble like Carrara.

Near the village of Simou on the secondary loop-road from Ktima to the main Polis road there is an exposure of igneous rock which is apparently faulted against unaltered Idalian chalk, and is much crushed at the line of junction. A remarkable assemblage of various types of igneous rocks occurs on the road from Ktima to Tala, just beyond the village of Emba. Here, within a few square yards, are irregular angular masses of diallagite, serpentine, spotted purple andesite, grey and green felsite, green spilite, etc., and a few yards further on is an exposure of greenish banded felsite much slickensided, shattered, and crushed into irregular fragments, having a brownish glaze on them. All around are hillocks of serpentine and of the spotted andesite forming bare rocky outcrops, but the serpentine is especially shattered and crushed at the margins. In the road-cutting at this place there are considerable exposures of *terra umbra* and soft yellow decomposed serpentinous material, and in addition there are red slates and shales with grey or white flinty beds (hornstones), similar to the so-called Kythrean beds near Mamonia, dipping to S.S.E. at 30–45 degrees, but their relation to the igneous rocks is obscure. The predominant rock is the andesite, which is often vesicular and apparently encloses masses of the other rocks. There are also here peculiar isolated masses of compact tough marmorized limestone, which rest directly on the serpentine and form rugged outcrops on conspicuous knolls. Probably they are of the same age as those at Petra tou Roumiou, with which they are lithologically identical.

Near the village of Mamonia, north-east of Ktima, there is a remarkable line of disconnected rugged masses of similar marmorized limestone, forming conspicuous isolated tall crags and pinnacles on both sides of the valley; the masses belong to a broken band of limestone having the beds nearly or quite on end, and the blocks are enclosed in a huge mass of serpentine and related rocks which stretches westwards across the valley towards Stavrokono. Higher up the road towards the latter village we find basalt invaded by diabase, but the basalt appears itself to have invaded the serpentine, the contact-margins of which are greatly shattered and crushed. There are also thick irregular beds of *terra umbra* and decomposed igneous rock associated with the serpentine. The supposed Kythrean beds crumpled up amongst these igneous rocks near Mamonia have been mentioned above. The typical Idalian chalk is seen regularly bedded and in contact with the serpentine on the hill above Mamonia, but has not suffered the least alteration, so that it is completely different in character and behaviour to the massive marmorized limestone " horsts " in the serpentine, which are probably of Trypanian age. In Bellamy's map of Cyprus an inlier of Trypanian limestone is indicated near Akourso, which is a village further to the west, but none is shown near Mamonia, and it is strange that the conspicuous series of detached limestone outcrops and the large development of igneous rocks above described in this locality and near Emba, as well as on the coast at Petra tou Roumiou, should have been omitted.

CONCLUSIONS.

From the preceding observations on the igneous rocks on the fringes of the Troodos complex and in the Northern Range we are led to conclude that there were several periods of igneous activity, but all of them seem to be earlier than the deposition of the Idalian beds. The occasional silicification of the latter near the contact appears to be explicable on the supposition of later hydrothermal action, as Cullis and Edge suspected. Some of the rocks (e.g. the pillow-lavas) were probably submarine flows and were poured out only shortly before the deposition of the Idalian sediments; the vesicular andesites may probably be included in this group. In no clear case has it been proved that Idalian beds are penetrated by igneous intrusions, and in many cases (as near Yerasa) rolled fragments of the latter are included in the calcareous beds. The Koronia limestone, whatever its precise age (2, p. 29), is also later than the igneous rocks (including the dykes) on which it rests, for there is a conglomerate of the latter at its base.

The serpentines and associated ultra-basic rocks (and perhaps the few occurrences of felsite) are earlier than the pillow-lavas and andesites, and near Emba masses of the serpentine are included in the andesite. It is possible that here we have the site of a volcanic vent. The relations of the serpentines and allied group of igneous rocks to the Idalian beds along the borders of the Troodos Mountains clearly indicate the existence of a considerable lapse of time between their respective formation, but the serpentines are undoubtedly post-Trypanian. Tectonic movements have locally caused the soft calcareous beds and harder more resistant igneous masses to show crushing and shattering at their junctions, resulting in the brecciation or fissility of the adjoining rocks.

In the case of the Northern Range the isolated occurrences of igneous rocks are mostly in the heart of the Trypanian outcrops, but it may be suspected that the fissile and crushed limestones in contact with them are not of Trypanian but of Lapithos age, as, indeed, Bellamy suggested, though it is difficult to establish at present the true age of all of them without much further work.

With regard to the Kythrean Formation, the occurrence at their base of conglomerates of rolled pebbles of igneous rocks (greenstones, etc.), and the fact that much of the material of which the sandstones are composed is of volcanic origin, point to the existence of pre-Kythrean igneous rocks, a fact often noticed before now. In no case has the present author observed in the Northern Range a contact between Kythrean and igneous rocks, and such does not seem to have been anywhere recorded, but on the flanks of the Troodos Mountains the supposed Kythrean red sandstones, shales, and flinty beds are intimately associated with the igneous rocks, and are crumpled and crushed just as are the supposed Lapithos beds in the Northern Range, to which formation they may, indeed, belong. Much further work is, however, necessary before the intricate relations of the various igneous rocks to each other and to the Tertiary beds can be completely determined.

Notes on the palaeontology and the correlation of the sedimentary Tertiary beds of Cyprus with those of other parts of the Mediterranean area will be given in a subsequent paper.

Postscript.—Since the above was written it has been brought to my notice that Prof. J. W. Gregory suggested some years ago that the continuation northwards of the old crystalline and metamorphic rocks of Egypt, the strike of which is almost at right angles to the trend of the Tauric folds, is to be found in the south-west of Cyprus and again on the opposite coast of Asia Minor. But this hypothesis awaits confirmation.

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On Continental Drift and Cognate Subjects.

By R. H. RASTALL.

I. SOME ANALOGIES.

A SUITABLE alternative title for the first section of this paper would be "Impossibilities and Geology". In point of fact it deals more with other matters of a diverse kind than with its own proper subject as implied in the principal heading. The discussion of the theory of continental drift has now reached such a point that it is believed that the setting forth of a few useful analogies may possess some value. It is hardly too much to say that the present status of the controversy is that geological evidence continues to accumulate showing that lateral movement of continental masses has taken place, as is indeed admitted, either directly or tacitly, by many of the opponents of the Wegenerian theory, while mathematicians and cosmogonists continue to reiterate that such is impossible. Now the real meaning of this attitude is that the mathematicians and astronomers have not yet discovered a cause, which is not by any means the same thing as proving that there is no possible cause, a philosophical distinction which is very commonly disregarded. A similar state of affairs has existed several times before, even in some of the more important problems of quite modern geology.

There are at least three geological problems of first class importance in which useful analogies to the present situation may be found. The first to be considered here is the Helmholtz-Kelvin estimate of the duration of geological time from the assumed rate of cooling of the earth, based on the underground temperature gradient and the conductivity of the rocks. It is unnecessary to give details of this so well-known argument. The point here is that the whole of it was based on the assumption that the earth had an initial supply of heat-energy which could not by any means be increased, and the upshot was that a possible duration of geological time was deduced which was manifestly insufficient for the deposition of the known thicknesses of sediment and for the evolution of the organic world. This argument was of course rendered completely valueless by the discovery of radioactive disintegration of elements, thus providing an energy supply available for an almost indefinite extension of past time. Whereas geologists then had to be content with a very few tens of millions of years, they can now think in thousands of millions: and yet the argument was perfectly sound on the data then available for mathematical treatment, only the existence of the most important factor was unsuspected.

The second analogy is afforded by that perennial subject of discussion, the cause of ice ages. No one at this time of day will venture to deny that glaciations have occurred on an enormous scale in many parts of the world and at many different times in the past, and yet no general cause has been discovered. So far it has been easy to prove that every possible suggestion is either quite inadequate or mathematically impossible. Apart from all questions of continental drift the Permo-Carboniferous glaciation of Gondwanaland bristles with "impossibilities" and yet there is irrefragable evidence that it did occur.

Parenthetically it may be observed that if the glaciations of South Africa, India, Australia and South America did occur in their present different positions at the same time, it makes the problem even more difficult than if they all formed part of one big ice-cap. Furthermore both in South Africa and Australia glaciations have been numerous in fairly low latitudes at different and widely separated periods of earth-history, so that the Permo-Carboniferous tillites are by no means an isolated set of phenomena: generally speaking, glaciations seem to have been less numerous in the higher latitudes than in the lower, so far as our present knowledge goes. All of these facts are at present inexplicable.

However, this is a digression from the main point, which is that so far no one has found any satisfactory explanation of glacial periods, either cosmogonic, geographical or climatic; most of the astronomical theories, if they explain any thing, prove far too much: that is to say they depend on functions which should be cyclically recurrent, and most of them too frequently, taking into account modern views of the duration of geological time. Nevertheless, glaciations did occur, and the last one, which is possibly still in progress, showed minor epicycles superposed on the main cycle. We still await the explanation, but no one maintains that glacial periods are impossible.

As our third analogy we may take mountain-building, and in particular the formation of the great flat fold-sheets (nappes or Decken) of the current theories of Alpine geology. This point has been admirably brought out by Dr. van Waterschoot van der Gracht in his introduction to the recent American symposium on continental drift. He here points out that the existence of such an intense degree of crumpling of the crust as is now universally accepted for the Alps and the Himalayas was for long violently opposed by many geologists, including Professor Heim, who was later converted to one of its strongest protagonists. However, the demonstration of the reality of such shortening of the crust did not in any way explain how it was done, which is after all what we really want to know. It is clear that somehow the outer shell of the earth has been tremendously crumpled, and still more important, that this crumpling has been concentrated in comparatively narrow belts. The shortening associated with the Himalayan folds is now estimated as of the order of 1,800 miles, which is an important fraction of the earth's circumference. If this crumpling could be undone by pulling at the south end of India, Cape Comorin would then lie not very far from Madagascar, and a flattening out of the Alpine Chains would easily fill up the Mediterranean. (Alpine Chains here means all the Tertiary folding of southern Europe and northern Africa.)

This last remark brings us up against another point of first-class significance. The accepted theories of Alpine structure, as expounded by Argand, Staub, Collet and the Swiss school generally, depend to a very large extent on a supposed pressure of Africa against Europe, with subsequent retreat of the southern block. We read of certain elements of Alpine scenery as bits of Africa left stranded on Europe; and these are illustrated by striking photographs of the Mythen and various other Alpine peaks. What is apparently meant here is that these mountains are portions of the floor of the Mediterranean geosynclinal that have been forced over the European foreland and left isolated when the northward force slacked off and the African crust-block again retreated to the south. This sounds remarkably like continental drift, although it is not explained why Africa first advanced northwards and then retreated to the south. Any way, in the usually accepted theories of Alpine structure it is implied that Gondwanaland barged into Eurasia with great force. This is an intelligible proposition, whichever way the absolute movement may have been. On the other hand we have the great fold-chains of the Pacific coasts, which have been squeezed violently against nothing at all: another paradox.

But there is a further consideration connected with this same type of mountain building that has not yet perhaps received the attention it deserves. In all the standard figures showing sections across the Alps and similar chains, we see successions of normal sedimentary, usually marine, strata, folded up in loops many miles in length. A useful example for the purpose of discussion is afforded by the coloured sections at the end of Schmidt's now rather old book *Bild und Bau der Schweizeralpen.* These sections are at any rate to true scale, horizontal and vertical. In all such reconstructions normal hard sedimentary strata are shown folded up like a table cloth when it comes back from the wash, involving a very high degree of plasticity when looked at as a whole. Now from known data as to density, tensile strength, crushing strength, etc., of rocks, it would probably be perfectly easy to prove mathematically that such folding could not occur, especially since in the case of Tertiary chains there could have been little or no superincumbent load. It is indeed high time that some one should undertake a mathematical investigation of the mechanics of nappe formation. The results would doubtless be surprising. This question of load is one of the really important points in Alpine tectonics, which has never yet been tackled seriously.

Here, then, we have three instances in which mathematical theory has either led to completely wrong results, or failed to produce an explanation, or has not yet tackled one of the fundamental points of tectonic geology. All of these cases lead to "impossibilities" which nevertheless have occurred. Is it then too much to ask for a suspension of mathematical judgment on the problem of continental drift, until geology and other sciences of observation have shown whether such drift did or did not take place ?

II. LAND BRIDGES.

Ever since the establishment of the doctrine of evolutionary descent biologists have been faced by the necessity of accounting for the existence of closely allied forms of life in far distant areas without intermediate stations. To account for these facts they have been in the habit of gaily postulating the appearance and disappearance of great masses of land where now are deep oceans, without much, if any, consideration of whether such a thing is physically possible. Unfortunately many eminent palaeontologists know little or no geology, not to mention all the other sciences that bear on the points at issue, and they do not in any way realize the difficulties inherent in their geographical revolutions.

The whole subject of land bridges of this type has been well summarized by Wegener, who based his discussion largely on the work of Arldt. It is not proposed here to give a general discussion, but merely to illustrate the magnitude of the geographical changes thus invoked by reference to one or two selected cases, which have a direct bearing on the possible former connection of the southern continental masses. It may be merely noted in passing that biologists and palaeontologists have joined up nearly all the continents at numerous geological periods in order to account for the present distribution of many families of terrestrial animals and plants.

The first case to be discussed is that of the struthious birds, the ostrich, the emu and the rhea, which, as everyone knows, are now found in Africa, Australia and South America respectively, while the second case is the occurrence of marsupials in South America as well as in Australia.

Now South Africa, South America and Australia are respectively about 6,000 miles apart, whether we measure the distance along a parallel of latitude, say 35° S, or directly across the south pole. The close similarity between the members of each of these groups, whether we choose the birds or the marsupials, implies a land connection between these three areas (or in the case of the marsupials of two of them) during the Tertiary. It may be granted that a land connection between South America and Antarctica does not present insuperable difficulties from the point of view of physical geography, as shown by any bathy-orographical map, but biologically the matter is not quite so simple. It is difficult to believe that opossums could have lived around the south pole at so recent a date and even if it is supposed that the Antarctic like the Arctic regions were warm in the Tertiary, of which there is as yet no evidence, there still remains the gap of some 2,000 miles between the Ross Sea and Australia. Here there has been revealed so far nothing comparable to the islands and shallow water between South America and Antarctica.

In the case of the ostrich-emu-rhea group the difficulty is still greater, because there is absolutely no evidence of any submarine link between Africa and any of the other three continental masses. It is surely unnecessary to labour this point further. The conclusion is obvious. In order to account for the present distribution of this group we must either assume a former close juxtaposition of these great continental masses, or the existence and disappearance of land bridges of continental magnitudes in comparatively late geological times.

Now it may reasonably be asked whether any biologist, palaeontologist or geologist has ever fairly and squarely faced the problem of the means by which a land mass measurable by thousands of miles can be brought into existence, and still more cogently, the manner in which such a land-mass could be made to disappear. The second of these problems is in point of fact by far the more difficult. It is conceivable that by contraction of the crust along a geosynclinal a long narrow mountain range might arise across an oceanic basin: possibly something of the sort did occur between South America and Antarctica, though this has recently been doubted by good authority. This is an exceptional case, and there remain many instances where nothing of the sort can have occurred, since no trace of the former connection remains. If such a ridge did arise across a true oceanic basin, it would necessarily consist of sima and would therefore be unstable, because not compensated, and we do not know of any large land areas composed of sima.

It is of course quite impossible that a sial continent could suddenly arise from nowhere.

The converse of this last statement brings us to the real crux of the problem, which is, how a land-mass of continental magnitude is to be got rid of if it once existed. The sinking of a sial continent into the depths, giving place to a true oceanic area, is a flagrant contradiction of the principle of isostasy, and the removal of such a land-mass by denudation is also manifestly impossible. It is of course quite true that parts of the existing continents have at various times been widely flooded by epicontinental seas, but this is a very different proposition, involving a complete interchange of oceanic depths and continental elevations. Such would be the case for any land-bridge joining Africa to South America or to Australia.

In this discussion all reference has deliberately been omitted to the frequently quoted case of Atlantic land-bridges between Europe and North America. This is admittedly a difficult and doubtful subject and has recently been discussed in very great detail by Professor Gregory. Owing to the existence of the Central Atlantic ridge and the supposed occurrence of a sial floor to this ocean, which rests on somewhat insufficient evidence, the relations are by no means clear, and it is impossible to state anything definite. Furthermore the linking up of fold-ranges on the two sides of the North Atlantic is still a matter of doubt and very different opinions continue to prevail.

The conclusion of this section is therefore that the conception of land bridges on a continental scale, extending for thousands of miles, presents very great geographical and geodetic difficulties, and that so far no reasonable explanation of the mechanism of the formation and disappearance of such bridges is forthcoming. Professor Gregory has recently said " If isostasy is so stated that it is inconsistent with the subsidence of the ocean-floors, so much the worse for that kind of isostasy ", and this statement has apparently the approval of Dr. Jeffreys. But is there any other kind of isostasy ?

Yet we have undoubted biological and palaeontological evidence of some kind of former connection between now widely separated land-areas, constituting a geological incompatibility of the first magnitude. The supposed existence of such bridges has been accepted with little or no question by most geologists, apparently because it is the " orthodox " view. The fact of the matter would appear to be that in reality they never thought about it at all: otherwise the difficulties would at once have been apparent, but a well-established dogma is not easily displaced, and British geology above all is dominated by orthodoxy. At any rate it is clear that the conception of continental land-bridges is in need of drastic revision and investigation in the light of modern knowledge.

III. THE ORIGIN OF THE CONTINENTS.

It is obvious that any theory concerned with the continents and their mutual relations must take into account the events to which the primary formation of such land-masses were due. It is impossible to obtain a complete grasp of any problem unless we get back to fundamentals, and in this particular instance this is specially necessary, since we have to explain among other things the very existence of the continents, and above all the remarkable fact that they occupy only about one-third, or less, of the whole surface of the earth. Furthermore recent work has shown that there is a very marked difference between the physical properties of the continents and the floors of the oceans, as briefly expressed in the definitions of sial and sima. What we have to explain first of all is, why masses of light rock form only one-third of the earth's surface, leaving aside for the moment all questions of isostatic compensation and dealing only with the simple fact, which will hardly be disputed.

In order to arrive at any reasonable conception of this fact we have, in the opinion of the present writer, to go very far back in earth-history, and here the matter becomes highly complicated, because there are so many different points that really need consideration all at once. However, the subject can be simplified down in one way, since all recent writers appear to be agreed that whatever may have been the origin of the earth, it must have passed through an incandescent molten stage. This is where the province of the physico-chemical geologist really begins; for this purpose all controversy about the relative merits of the nebular and planetesimal hypotheses may be ignored as irrelevant, since the final result appears to be the same, namely, a molten globe with its cooling crust, as long ago envisaged by the penetrating genius of Lowthian Green, a man far in advance of his time.

This incandescent molten globe then is evidently amenable to the laws of physical chemistry, since it constitutes a closed system in the sense of the phase rule. It is in fact primarily a highly complex solution, and is therefore subject to the known laws that govern the behaviour of such a solution. Now we know that the present earth contains silicates and sulphides, and by a process of reasoning, perilously like arguing in a circle, we conclude from the analogy of meteorites that it also includes a good deal of nickel-iron. This conclusion is confirmed by the high density of the earth as a whole, which is about twice that of the sial crust. Now the everyday facts of metallurgical practice show that at blast-furnace temperatures metals, sulphides and silicates are not miscible in all proportions, but form immiscible liquids. Therefore at some stage of cooling the earth must have constituted a three-phase system, the liquid non-consolute layers being arranged in the order of density, with a metallic core, an intermediate shell of sulphides (perhaps with oxides, as suggested by Goldschmidt) and an outer layer of silicates. The boundaries between these phases constitute the discontinuities revealed by earthquake observations at 1,200 and 2,900 kilometres.

It is of course the fate of the silicate crust that mainly interests geologists: the rest may be left to seismology and geodesy. Since we have here to deal with silicates, it is permissible to apply the laws of magmatic differentiation, even on this very large scale. It is hardly necessary to return at this stage to the simple fact that it is now known that the continents consist of light silicates (sial) and the ocean floors of heavier silicates (sima). This may be taken for granted, but something must be said later as to the constitution of the sima, which is not necessarily altogether in the basaltic phase.

This is not the place to discuss in detail the latest views as to the exact thickness of the sial blocks that form the continents. The most recent estimates vary between 60 and 20 kilometres, or even rather less; some figure of this order will serve our purpose. What we have to consider then is a mass of basic rock some hundreds of kilometres thick with a much thinner acidic layer at the top. Here the petrographical analogy of some of the largest known basic sills; the Palisade Traps, the Sudbury nickel-intrusive, Insizwa, and so on, comes into account. All of these show a more acid layer at the top, usually a " red rock " or micropegmatite. These acid layers are now universally regarded as resulting from magmatic differentiation. Opinion is still somewhat divided as to the nature of the physico-chemical processes that have led to this differentiation, but most petrologists will now probably agree with Bowen that crystal-sinking has been a very important factor. It seems quite clear that a basic magma cannot split into two immiscible liquid phases. At any rate we know that large intrusions differentiate somehow into an upper acid and a lower basic layer, and it is a fair inference that a silicate world-shell would do the same.

But the natural inference from this hypothesis would be that the whole earth should be covered by a uniform layer of sial, which of course it clearly is not, and this fact has to be accounted for. It has been somewhat vaguely suggested by various writers that this sial crust has somehow rolled itself up into continents, covering only part of the earth, leaving intervening ocean spaces with a floor of more or less bare sima, but this is not probable or satisfactory. The phenomenon can be accounted for in another way, which has already been set forth by the writer in *Nature.* This does not however seem to have attracted the attention of any geologists, so it is repeated here in a much abbreviated form.

It must not be forgotten that while all these processes of differentiation were going on the earth was rotating rapidly, perhaps much more rapidly than now, and that solar tides would produce a marked effect in a liquid globe. It was long ago suggested by Sir G. H. Darwin and by Prof. Pickering that a rotating liquid globe subjected to tidal influences would undergo much distortion, and would finally break into two unequal parts, to wit, in this instance, the earth and the moon. This conception of fission by tidal resonance seems to be accepted by many mathematicians. It affords at any rate a practicable means of origin for the moon. Accepting this theory, let us see whether ascertained facts are consistent with it.

It seems likely, in the first place, that the pear-shaped and afterwards dumb-bell shaped smaller protuberance that broke off as the moon would consist of the superficial layers of the original liquid sphere, and that there would be a sort of drag on the outer layer. Now this outer layer would necessarily consist of the sial crust as above postulated, especially since this would necessarily be the first part to solidify on cooling. When this partly solidified portion of the crust shot off with a rotational spin, it would naturally roll itself up into a ball, and being still at a very high temperature would undergo differentiation and later give rise to volcanic phenomena on its own account, as the moon certainly did.

Assuming therefore that the moon consists mainly of sial stripped off from the surface of the earth, and that the sial blocks still remaining cover about one-third of the earth's surface it remains to determine the average thickness of the layer thus removed. A simple calculation shows that to form a sphere of the size of the moon the thickness of material to be stripped off from two-thirds of the earth's surface is about 40 miles, or 60 kilometres, a figure surprisingly near to that generally assumed, till lately, for the thickness of the sial blocks.

The theory can also be tested in another way; that is, by a consideration of the density of the moon as compared with that of sial and sima. This will be found also to be in substantial agreement. The density of the moon is given as 3·4, which is of course distinctly higher than that of sial, and even a somewhat high figure for sima. This is easily explained if we accept the most recent estimates for the thickness of the sial, 20 kilometres or even less. Then it can be assumed that the moon tore off a considerable amount of the lower silicate layer, which has a density not far short of this figure, on the most moderate estimate, while naturally there must have been increase of density by compression within the moon itself. Dr. Wagner has recently shown in a striking paper that in South Africa, over an area of at least a million square miles the basic layer at a depth of some 60 kilometres is in the dense eclogite facies, and not basalt, so that it is a fair inference that similar conditions exist elsewhere. So far, no conclusive evidence whatever has been adduced for the existence of the light basaltic glass of Daly and Jeffreys, at any rate within the later geological periods.

On this hypothesis we are left with the conception of a highly heated earth, stripped of two-thirds of its outer skin by the formation of the moon, with a remaining third of more or less solidified continental sial masses floating in a molten substratum. This remaining third constitutes the primitive form of what is now coming to be known by that horrible word *Pangaea*. This may be envisaged as a crystalline crust, floating on that part of the earth that was antipodal to the scar left by the departure of the moon, namely the Pacific region, where sima is dominant. Since the main mass of the continents were at this stage all aggregated together into one block the centre of gravity of the whole earth would be slightly displaced on the departure of the moon, and the continental mass under the influence of rotation and tides, and possibly other more complicated forces, would tend to break up and slip about, perhaps producing something very like Daly's sliding continents.

It remains of course for future investigation to determine whether it is dynamically possible for a stripped-off portion of a planetary skin to roll itself up into a spherical satellite, and much depends on the degree of consolidation of the material at the time of its departure. But it is submitted for serious consideration that this is the easiest method of accounting for the curiously limited distribution of sial blocks. There is of course nothing original in this theory of the birth of the moon : it was long ago worked out by Darwin and others as a mathematical possibility, and has been adopted by various geologists, some of whom have assigned the event to a comparatively late geological date. It is however an essential feature of the present form of the theory that the splitting should have taken place at a very early stage of earth-history, when there was a more or less solidified and magmatically differentiated crust with a liquid phase (or succession of phases) below it, the whole earth being in a plastic and mobile condition. Whether the continents have drifted or not, they would thus be given a fair chance of doing so.

Some Characteristic Structural Types in Eastern Asia and their Bearing upon the Problem of Continental Movements.

By J. S. LEE.

(*Continued from p. 431.*)

EXPERIMENT IV. (Pl. XVI, Figs. 4, 5, 7 ; Pl. XVII, Figs. 5 and 6.)

PLACE two or three fingers of the left hand in a fixed position and lay the right hand by the side of the tip of the fingers in such a position that the former makes an angle of some 20° to 30° with the fingers. Then turn the right hand clockwise, there will appear a series of arcuate folds around the tip of the fingers as well as some *échelon* folds between the left and the right hand. The greater the angle through which the right hand is twisted, the more predominant will the folds become. In this way we can produce the cranium and the limb of the system but not always the crown, which only begins to appear when the entire palm of the right hand is placed flat on the paper and twisted through a larger angle.

(*e*) *ϵ or Epsilon Type.*—Among the several structural types described here, the epsilon is perhaps the most widely developed, the most easily recognizable, and the most instructive for the study of earth-movement. The whole system may be confined to a small area, or may cover more than one continent. The structural outline of the system is exceedingly simple. It consists of a frontal fold-arc, termed the wings, and a central ridge termed the axis. When developed in an ideal form, the system possesses a bilateral symmetry. The axis of the system is also its axis of bilateral symmetry. Bilateral symmetry is, however, sometimes disturbed through local or regional complications. As a rule, the axis is almost perpendicular to the middle part of the arcuate front, or the apex. The terminal part of each wing is often turned forward so as to form a series of reflex arcs. Such reflex arcs are so arranged that they, together with the main fold-arcs, always describe a series of S-shaped curves. The wings and the axis never become parallel, however highly compressed.

The two wings together with the apex may consist of continuous series of compressed fold-arcs, or they may consist of heterogeneous elements. In the latter case, each of the wings may be composed of a succession of complicated folds or thrusts, or may include an ancient massif already folded in an entirely irrelevant trend. Whichever may be the case, the two wings and the apex form a continuous whole, which can be recognized by studying the tectonic history or palaeogeography of the region concerned. When the system is developed on a large scale, the wings are usually formed by an anticlinorium or anticlinoria, on the inner side of which a geosyncline stretches out in a similar arcuate form. The marginal plain of such a geosyncline always extends towards the region where the axis of the system lies.

The structure of the axis is usually quite simple, even if that of the wings is complicated. The axial lines are, in the overwhelming majority of cases, almost strictly rectilinear, at least for a considerable length in the middle part. Only occasionally do they tend to bifurcate or bend towards the posterior part of the axis, namely, the part farthest removed from the apex, and tend to split into short branches towards its anterior end. The axis may be composed of a simple, broad up-arching or a geanticline supplemented by a geosyncline, or may consist of a series of compressed folds often accompanied by thrusts.

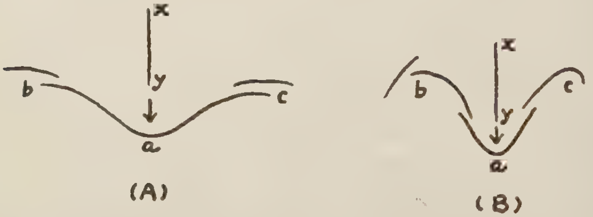

Fig. 6.—Two forms of epsilon structure. *A*, broad form; *B*, compressed form; *a*, apex; *ab*, left wing; *ac*, right wing; *b* and *c*, reflex arcs; *xy*, axis; arrow indicates direction of principal movement.

It is often possible to trace the stages of development of a given epsilon system. In its young stage, the wings are folded into normal synclines and anticlines and broadly bent; the axis is far removed from the apex; and the structure of the axis is extremely simple—a simple anticline or the like. In the more advanced stage, thrusts begin to appear in both wings with a general tendency to thrust over towards the interior of the system. At the same time the axis extends farther towards the apex, and also attains a more complicated structure which may include thrusts. Consequently the convex front of the wings becomes more acute. In the senile stage, thrusting becomes still more pronounced in the wings, apex and the axis; and block-overthrusting (Schollenüberschiebung) is usually found in the wings. The axis not only extends still farther towards the apex, but may bend or bifurcate in its posterior part and split into a number of short ridges at its anterior end. The angle between the two wings becomes so acute that the whole arcuate front now almost assumes the form of U or V. Even in this case, it is doubtful whether the axis actually comes into contact with the apex.

In distinguishing these stages we are assuming the system to be developed in a homogeneous medium or uniform environment. If the system be developed at the very beginning near or in between some ancient massifs which are already arranged at a sharp angle to each other, then the system will at once attain some senile aspects. Conversely, if the arcuate front be of a very broad nature in the initial stage of its development, then the wings may not be able to develop an acute curvature even if the senile stage is already reached.

Throughout its young and mature stages of development, the region covered by this system seems to be immune from other types of deformation except those of local character ; but in the senile stage, flexures or fractures belonging to entirely different systems may break through. Such alien features have nothing to do with the system proper, and must be carefully differentiated.

Because of the important rôle that the epsilon type plays in determining the major structure of Eurasia, and because of the fact that the establishment of this system has served as a basis for the recognition of other systems, the writer may again be excused for narrating some personal experience in a somewhat tedious struggle for light. During the last eighteen years the writer has three times had the opportunity to journey across the monotonous plains of northern Eurasia as well as the singular range of the Ural. Each time he was profoundly struck by the boldness and yet simplicity of that marvellous range which abruptly rises above the vast plains on the east and the west. Its apparent irrelevance to the other mountain systems of Eurasia adds to the mystery of its existence. In vain he has searched the available literature for a satisfactory explanation of the underlying tectonic cause of that natural divide between Europe and Asia, and for that matter for any explanation at all. Only a few years ago a presumptive solution was reached by supposing Eurasia as a gigantic beam supported at both ends and bent in its middle portion towards the south. As a consequence of that bending east and west compressive stress would naturally be aroused farther to the north.[1]

The bending effect is plainly exhibited in the present mountain ranges extending from Southern Europe to Central Asia. This needs no further comment. But the question must be answered why should a mountain-range of Palaeozoic date, namely the Ural, bear any relation to that Eurasian system which arose in Tertiary times. Before the Hercynian movement took place, the position occupied by the present Ural was obviously the site of a geosyncline—the Uralian Geosyncline. Similarly the girdle of Tertiary mountains in southern Eurasia were also relatively narrow strips of sinking land known under various local names of geosynclines. As we have already stated, a geosyncline is but a complementary feature of a geanticline. Those geosynclines must then have had their counterparts in their immediate neighbourhood and also must have assumed a similar trend. This would lead us to conclude that the essential features of the great Eurasian epsilon system had already been established in pre-Hercynian time.

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[1] J. S. Lee, "The Fundamental Cause of Evolution of the Earth's Surface-features" : *Bull. Geol. Soc. China*, vol. v, Nos. 3–4, 1927, pp. 234–5.

With the outbreak of the Hercynian movement we know that the Tianshan and Kwenlun geosynclines were folded in Central Asia, and the great Variskian or Hercynian system rose in Europe. Although it requires further research to establish the position and trend of the Palaeo-Iranian ranges, yet there is little doubt that they existed as a whole in much the same way as the present Iranian mountains. We should be less confident in making this sweeping statement had we not been able to recognize the fact that the longitudinal chain of the Ural is but a part of a whole epsilon system.

The basic idea of the epsilon type of structure is by no means new. E. Argand[1] has already discussed it at some length under the designation of " Virgation du premier genre, double ". Suess recognized its essential characters long ago in the structure of the Amphitheatre of Irkutsk.[2] This ancient nucleus of Eastern Asia affords a splendid example of the epsilon type on a moderate scale. The western wing of the system starts from the west of the Yenissei Horst, extending south-eastward along the East Sayan until it comes to the south-western corner of the Lake Baikal. Here the Archaean rocks of Elovski Khrebet are seen to strike W.N.W., showing that the apex of the system is approached. In the island of Olkhon and in Sviatio Nos, which are located in the middle of the lake, the ancient rocks exhibit a definite north-east strike. Here the structural axes do not run parallel to, but obliquely across the lake. Hence they are designated Transbaikalian. The Transbaikalian trend extends north-eastward up to the Vitim Plateau, and even further north. The Sayan trend coming from the north-west and the Transbaikalian trend from the north-east appear to meet in the narrow horst of Primorski Khrebet, which consists of amphibole-gneiss of Archaean age. At the junction of the two directions, the rock has almost a meridional strike. The dominant N.–S. strike is said actually to appear at a place some distance to the north of Angara. Thus in the southern part of the Amphitheatre, and within it, we are able to establish the wings, the apex, and the axis of the epsilon system.

The whole system extends, however, to a much wider extent than the Amphitheatre. Its north-western wing apparently reaches as far north as the south-western border of the Taimyr massif on the one hand, and the Sailiugem and West Sayan on the other. The latter ranges form a reflex arc with its concave side facing the south. Its north-eastern wing reaches the sources of the Vilui in the north and the Vitim Plateau on the south. In the latter region we find again a series of reflex arcs with their concave side facing the south. The development of these two sets of reflex arcs—the Sailiugen-Sayan and the Vitim—is highly characteristic of a senile epsilon as will be shown by a later experiment. In the Anabar massif, which is situated between the two wings and almost in line with the apex of the system, the gneiss possesses a distinct meridional strike.[1] It is, therefore, evident that the axis of the system has also stretched far to the north. The southern limit of the system may be traced to the northern border of the Tannu-Ola, Khangai, and Kentei Mountains; for along the lower course of the Selenga we still find the two dominant strikes, the Sayan and the Transbaikalian, approaching the valley of the river from the west and the east respectively.

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[1] E. Argand, op. cit., pp. 207–10, fig. 2.

[2] E. Suess, op. cit., p. 85.

The origin of this system dates back to a very ancient geological time. According to Obrutschev, the wings, the apex, and the axis of the system had already been largely established in the later part of the Archaean or the "Archaeozoic Period". The several elements were orogenetically folded and dislocated at the end of the "Eozoic", which probably corresponds to the close of the Torridonian. Through this mighty movement the wings were overfolded or even overthrust towards the interior of the system, that is towards the interior of the Amphitheatre. By the end of the Silurian Period not only did the wings suffer an intense movement, but the areas within the prolongations of the two wings were also folded. Thus in the Angara district the Silurian is folded in a W.N.W. trend, and in the Vilui and the middle Lena in an E.N.E. trend. In these districts the folding is, however, less intense as compared with bordering zones of the Amphitheatre.[2] Even by as late as the Jurassic movement, parts of the system were again strongly compressed and horizontally dislocated.

From the fact that the Amphitheatre now forms a sharp V in its frontal part and that the axis of the system has almost, if not exactly, reached its apex, it appears quite certain that the system has reached its senile stage. Indeed the senile stage may have been already reached by the time when the Caledonian or the late Jurassic movements took place; for, otherwise, the east and west axes of alien origin would not be able to break through the Angara district as a consequence of those movements.

The second example of the epsilon type of structure occurs in north-western China. Here the western wing consists of the Nanshan Ranges in which Palaeozoic as well as Mesozoic strata are folded in a north-westerly trend. The north-westerly folds gradually merge into an E.–W. strike as they proceed south-eastward until they completely amalgamate with the western Tsinling between the longitudes of 105° and 108° E. The eastern wing is represented by parallel ranges curving along both sides of the Fenho Valley with their convex front facing the south-east. Although it has been generally held that the ranges bordering the Fenho Valley are due to normal faulting, yet evidence is not lacking for lateral pressure. For instance, on the border of the Western Hills of Taiyuan we find the Ordovician limestone almost standing on its end, if not actually reversed. In the Eastern Hills of the same district the strata often dip gently towards the plain without any visible fracture. As a whole it appears highly probable that these interior ranges of the Shansi Plateau were primarily produced through lateral pressure, locally accompanied by secondary faulting. The eastern part of the Shansi Plateau may be considered as a part of the eastern wing of the system ; for the eastern edge of the plateau or the Taihang Range, is also a very prominent feature, curving round in a fashion similar to the ranges bordering the Fenho. Along the Taihang Range we find sometimes monoclinal flexure, sometimes normal faulting, and occasionally local overthrust towards the interior of the plateau.

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[1] H. Buckland, "Über ein Gneissmassiv im nördlichen Sibirien": *Tr. Geol. Mus.*, I, L, 5, 1907.

[2] W. A. Obrutschev, op. cit., pp. 411–16.

The axis of the system is located at about longitude 106° 30′ E., and constitutes the famous Liupanshan or Lungshan of ancient Chinese geographers. This meridional hill range extends from latitude 35° N. northward for several hundred of kilometres and is almost everywhere capped by a soft Cretaceous shale intercalated with thin layers of oolitic limestone. The rock easily disintegrates into a crumbling mass. This fact led J. G. Andersson[1] to believe that the Liupanshan is a " mountain in the making ". Proceeding northward we find another nearly meridional range on the western border of the Ordos massif. This is the Alashan or the Holanshan of Chinese geographers. Highly significant is the fact that the Alashan is practically in line with the Liupanshan, though the northern part of the former range is slightly turned to the east. In the southern part of the Alashan W. H. Wong and C. H. Hsieh have noticed mighty overthrusts to the east. Although we have not yet obtained sufficient data to determine the exact ages of folding in these meridional mountains, it may not be far wrong to state that the Alashan is a much older range than the Liupanshan, though the former was undoubtedly also affected by post-Cretaceous movement. This conforms with the idea that the axis of the epsilon system generally advances towards its apex as the system reaches maturity.

The third example is found in the northern part of the Province of Yunnan and the south-western part of the Province of Szechuan. There, the arcuate front or the wings of the system constitute a series of highly compressed fold-arcs known as the Yunnan Arc. The innermost zone of the arcs approximately follows the elbow of the Kinshakiang or the Upper Yangtze, and is characterized by mighty overthrusts towards the concave side of the arc. The apex of the system is at about longitude 102° E. and latitude 25° 30′ N. As the region is not yet fully explored from the tectonic point of view, the detailed structures of the wings are not yet known with certainty. Judging from the abbreviated account given by V. K. Ting, it appears that the axis is located in the Lungtsaoshan which forms the watershed between the Tachongho and Anningho, both of which feed the Kinshakiang from the north.[1] The Lungtsaoshan is a meridional range running along the longitude of 102° E. from the district of Yuanmouhsien (about 25° 30′ N.) to the north of the latitude 27° N. It consists of schist, metamorphosed quartzite and limestone, much folded and often thrust. This example represents a highly compressed type of the epsilon system.

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[1] J. G. Andersson, " Geological Notes from Kansu " : *Bull. Geol. Soc. China*, vol. iv, p. 17, 1925.

All these cases so far referred to cover extensive areas with their anterior ends pointing towards the south. A fourth example is found in south-eastern China between the cities of Nanking and Chien-kiang. Here the epsilon system is developed on a diminutive scale, but in a superb manner, with its anterior end pointing to the north. If a chord be drawn between the west and east termini of the wings, its length is found to be less than 90 kilometres. The wings consist of a series of arcuate folds which are of the normal type in the western part, but become rather compressed and even slightly overturned towards the south near the apex, and somewhat shattered in the eastern part. The apex is located in the neighbourhood of Chuanshan where the strike of the strata sharply turns round so as to form a small arc with its convex front facing the north. Some 18 kilometres south of the Chuan-shan there arises a small meridional hill range, the Maoshan, extending southward for about 25 kilometres. The general strike of the strata exposed in the Maoshan is also meridional. The hill is in longitude 119° 20′ E.

Cretaceous strata are involved in the folding both of the wings and of the axis. There is little doubt that they were simultaneously effected by a post-Cretaceous movement. We are as yet uncertain as to whether the system had already been brought into existence before the post-Cretaceous movement. If that is the case, the earlier movement or movements must be of the same nature as the post-Cretaceous one; for strata ranging from Ordovician to Cretaceous in these hills are impressed with a similar strike, only locally differing in the amount of dip. As the low land surrounding these hills is covered by loess or recent alluvium so as to form a flat plain, the tectonic features of the system stand out with striking relief—an ideal case for text-book illustration.[2]

EXPERIMENT V. (Pl. XV, Figs. 1–3.)

Press the ball of the thumb or a finger tightly on the paper; then shift the thumb or finger towards a definite direction. A bundle of arcuate folds will be made to appear on the left and right sides as well as in front of the tightly pressed part of the paper. Behind the pressed part there appears simultaneously a single fold which lies nearly halfway between the two rows of lateral folds, and arranges itself roughly in line with the direction of the shifting movement. By this single process we can infallibly produce all the elements of the epsilon system. The greater the amount of movement, the more convex becomes the frontal arcs; at the same time the central fold, or the axis, extends forward with an increasing tendency to approach the apex. The posterior part of the axis may become bifurcated when the horizontal movement exceeds a certain limit, and when the system is developed on a large scale, say, by applying the whole palm.

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[1] V. K. Ting, "The Tectonic Geology of Eastern Yunnan": *C. R. Cong. Géol. Intern. XIIIme Session*, pp. 1155–60, 1922.

[2] C. C. Liu and J. C. Chao, *Preliminary Report on the Geology and Mineral Resources of Kiangsu*, pp. 19–23, Map, Section I (Geol. Surv. China), 1924.

This experiment affords the clearest evidence that the epsilon system is generated by a horizontal movement of the region involved in the system against some resistant tracts on the outer sides of the two wings and that the direction of the horizontal movement coincides with the trend of the axis. The apical part of the system effects the greatest amount of horizontal shifting in the whole system.

Many more types belonging to the unitary group may be distinguished; but those described above are among the most important, for they afford cogent evidence for determining the nature of regional movements. We will now select two important types belonging to the syntaxial group.

B. Syntaxial Systems.

(*f*) λ *or Lambda Type.*—Two sets of elements enter into the composition of the lambda type. Each set may be termed the limb of the system. The two limbs are arranged after the fashion of the Greek letter, λ; hence its name. The limb that corresponds to the dextral stroke of the latter generally consists of a powerful chain of the Cordilleran type slightly curved, and that corresponding to the sinistral stroke of the letter is composed of a series of structural lines which are orographically less significant, but possess a greater curvature. The two limbs may meet virtually or in reality. In the latter case the points of junction are often the sites of volcanic activity. This type only occurs along the continental border, and is frequently characterized by mighty thrusts, particularly in the limb that actually borders the continent.

This type exhibits some resemblance to the nu type inasmuch as both of them consist of two limbs arranged after the fashion of a somewhat curved V. The two limbs of the lambda system are, however, not of the same nature: the outer limb, namely, the one that corresponds to the dextral stroke of λ, is generally far more dominant than the inner one; the former, therefore, may be called the dominant limb, and the latter the subordinate limb. Moreover, in the dominant limb the axial lines are relatively few in number, and they run almost parallel while in the subordinate limb the axes are not only curved to a greater degree, but are far more numerous. Some of them may locally form the nu type. Thus it may be said that the subordinate limb of the lambda system may comprise nu systems of structure; but the nu system can never be identical with the lambda.

Three varieties can be distinguished in this type. The first variety is the lambda type *S. Str.*, or *normal lambda type*; the second may be termed *reversed lambda type*; and the third, *inverted lambda type*.

Examples of the normal lambda type occur in Korea and the Philippine Islands. The Korean Peninsula[1] is bordered on the east by a mighty range known as the Taipaiksan, in which B. Koto distinguishes three long axes running nearly parallel to the present coast-line. In the south-western part of the peninsula, the same author delineates several groups of structural lines. Some of these are attributed to the Sinoid, others are designated the Palaeo-Chosen system, and a third group, the Syopaiksan system. All these systems appear to converge towards the N.E., and diverge towards the S.W. or S.S.W. They may actually meet or even transect the Taipaiksan, or may die out before the eastern range is reached. The Taipaiksan represents then the dextral, or the dominant limb, and the other lines referred to, the sinistral, or the subordinate limb of the lambda system.

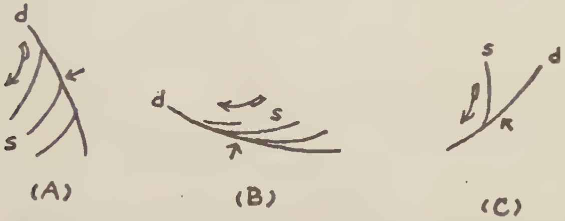

Fig. 7.—Different forms of lambda structure. *A*, normal lambda type; *B*, reversed lambda type; *C*, inverted lambda type; *d*, dominant limb; *s*, subordinate limb; tailed arrow indicates direction of continental movement; plain arrow indicates direction of induced pressure from the ocean floor. Note that the direction of torsional movement is not determined by the orientation of the lambda but by the nus which generally form the subordinate limb.

In the Philippine Islands the dextral limb of the lambda system comprises a number of Cordilleran ranges running along the eastern or north-eastern border of the islands.[2] The northern part of this limb coincides with the Formosa-Luzon line which forms a part of the Formosa-Borneo-Marianne system already described. In

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[1] B. Koto, *Journ. Coll. Scien. Imp. Univ. Tokyo*, vol. xix, 1903, Art. 1, pl. iv; E. Suess, *La Face de la Terre*, Tome iii, p. 1403, fig. 321.

[2] W. D. Smith, *Handb. Reg. Geol.*, Heft 3, 1910, p. 14.

Luzon there are three dominant axes marked by the Sierra Madre Range on the north-eastern coast, the great Cordillera Central extending from the northern extremity of the island to Benguet and the Zambales Range bordering south-western Luzon. The Sierra Madre Range runs almost strictly N.–S.; the Cordillera Central has a meridional strike in its northern part, but as it proceeds southward its trend appears to deviate therefrom gradually to the south-east. The Zambales possess a distinct E.S.E. strike throughout its length. The central range of Mindoro represents the innermost element in the northern dextral limb. Southward the same limb describes a distinct arc with its convex front facing the Pacific. In this southern part of the limb Smith recognizes three arcuate axes. The outer one traverses the Camarine Peninsula and Samar Island; the middle, which is the longest, emerges from a point to the south-west of Manila, passing the islands of Masbate, Leyte, and finally curving along the eastern coast of Mindanao; the inner one only appears in Mindanao extending between Camiguin and Savangani.

Just as in western Korea, the sinistral limb of the system consists of a succession of arcuate lines all curving towards the south-west. Their general disposition is shown by Palawan Island. Similarly disposed axes are to be traced in Panay, Western Masbate, Negroa, Western Mindanao, and the Sulu Archipelago. These lines seem to form a nu type as they proceed towards Borneo. It is because of the presence of this lambda system that the great nu-delta system of Formosa-Borneo-Marianne presents a rather complicated appearance.

The best example of the reversed lambda type is found in Sumatra and Java. Very valuable work has been done by H. A. Brouwer in these islands.[1] From Brouwer's contribution as well as from those of Tobler,[2] Verbeek,[3] Volz,[4] and others, it may be gathered that in Sumatra and the pre-Sumatra islands there occur a pair of geanticlinal axes curving gently towards the south-east and running parallel to each other. The first axis runs through the Simalu, Nias, Mentawei, and Engano group; and the second closely follows the south-western coast of Sumatra. The latter gives off numerous slightly curved branches towards E.S.E. Among the branch lines those emerging from central Sumatra, passing Banka, Billiton, and finally entering into south-western Borneo are the most notable. They proceed at first towards S.E. by S, then gradually turn round to S.E. by E. On Billiton the general strike is distinctly E.S.E. In the south-western part of Borneo the structural lines sweep round towards the north-east.

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[1] H. A. Brouwer, op. cit.

[2] A. Tobler, " Uber Deckenbau im Gebiet von Djambi ": *Verh. Naturw. Ges. Basel.*, 1917.

[3] R. D. M. Verbeek and R. Fennema, *Description géologique de Java et Madoura*, Amsterdam, 1897.

[4] W. Volz, " Zur Geologie von Sumatra ": *Geol. u. Pal. Abh.*, N.F., vol. vi.

The same thing happens in Java. There, the main line runs along the southern border of the island, and is continued eastward to Flores. From the south-western corner of Java a number of branch lines are set off which obliquely traverse the island, and extend as far as Madura and Kangean. A third notable branch is found on the islands of Bali and Lombok. Here the main line runs W.–E. while the branch line curves towards the north-east.

Thus we are enabled to see that the Sumatra and Sunda Islands arc is not a simple tectonic feature, but embodies two limbs of the reversed lambda type. The main range on the south-western and southern coast of the islands forms the dominant limb of the system corresponding to the dextral stroke of the latter, λ; the several branches which are set off to the south-east and north-east represent the subordinate limb, and as a whole correspond to the sinistral stroke of the letter. But unlike the cases in Korea and Philippine here the relative position of the two limbs is reversed.

Of the last variety, namely, the inverted lambda type, the writer has so far failed to find any typical example in Eastern Asia. It is, however, developed on a grand scale in Australasia. In the South Island of New Zealand there rises that noble range known as the Southern Alps. Although the detailed structure of this range is not yet known, it is quite plain that its main axis, or at least the north-eastern part of it, essentially conforms with the trend of the island. In the North Island the same range apparently does not continue; but "from Cape Terawhiti near Wellington to the eastern side of the Bay of Plenty there is a continuous chain of much folded slates and graywackes" constituting the Rinutaka, Tararua, Ruahine, Kaimanawa, and Raukumara mountains.[1] These are undoubtedly remnants of a much denuded and partially buried old range which has a general strike sensibly parallel to the Southern Alps. This line is apparently continued north-eastward under the sea along the Kermadec-Tonga Ridge.[2] Because of the scarcity of palaeontological evidence it is difficult to determine the date or dates of the movement which gave rise to these exposed and submerged ranges. Marshall seems, however, inclined to believe that they rose to prominence through the late Jurassic as well as Pliocene movements.[3]

These chains, together with the Kermadec-Tonga ridge, form the dextral limb of the lambda system. The sinistral limb of the same system comprise the Australasian festoons of Gregory. The most notable of these is the line that starts from the south-eastern corner of New Guinea, curving towards New Caledonia and the Auckland Peninsula of North Island. In the last-named area, the local strike of the rocks varies to some extent. But there is a range of hills extending from Whangarei to the Bay of Islands that shows a significant parallelism to the elongation of the Peninsula. Those forming the axes of the Great Barrier Island and the Coromandel Peninsula also closely follow the coastline. A third group of hills is said to run from Kawhia to the Hauraki Gulf with an apparent N. by E. trend. The local strike of the rocks does not seem always to agree with the axes of these hill-ranges. All these anomalies are well within our expectation; for coming from the north-west, these structural lines progressively enter into contact with the dominant limb of the lambda system. The process of syntaxis culminates in the volcanic area which occupies the central part of the North Island. The second line extends from New Ireland to Solomon, New Hebrides, and may stretch as far as the Kermadecs, but may die out before the Tonga-Kermadec line in reached. It is thus clear that the subordinate limb of this lambda system forms at the same time the crowning arc of the great eta system of Australasia and the Banda Islands already referred to.

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[1] P. Marshall, "New Zealand and Adjacent Islands": *Hand. Reg. Geol.*, vii, i, pp. 1–5, 54–60.

[2] P. Marshall, "Oceania": ibid., vi, 2, pp. 2–6, 22–3.

[3] P. Marshall, "Crustal Movements and Geotectonics in the Pacific Region," *Third Pan-Pacific Sc. Congr., Tokyo, Abstract A*, No. 164, 1926.

As the two limbs of this system open to the north, it seems appropriate to regard it as the inverted lambda type. The reason that this together with the normal and reversed lambda systems are considered to be varieties of the type is not only based on their morphological resemblance, but on the fact that they are generated by similar, if not identical, processes.

Experiment VI. (Pl. XVI, Fig. 2; Pl. XVII, Figs. 3 and 4.)

The lambda type of structure is not so readily obtainable on paper as those already described. Nevertheless, with a little practice and care something essentially similar to the natural form could be produced. What is more important is experience by which the operator will be able to demonstrate to his own satisfaction the nature of the mechanical processes involved in producing the figures. For the normal and reversed lambda types, the experimenter needs only to pull the left hand inward and sideward or twist it on the paper clockwise, and at the same time press the right hand in appropriate positions on the paper with an attempt to shift the latter towards the left. The movement exerted by the left hand will result in the formation of a series of folds which will be more or less bent according to the amount of twisting. These folds correspond to the subordinate limb of the lambda system. The movement exerted by the right hand will serve to produce one or several aggregating folds. They meet the other group of folds obliquely so as to represent the dominant limb of the system.

For the reversed type, it is best to place the thumb and second finger of the left hand on the paper at their full span; then place the right hand between the two fingers and to the right of a line connecting the two finger tips. Rotate the right hand clockwise with full force, repeatedly if necessary; folds of the reversed type will appear in succession.

These experiments demonstrate that all the three varieties of the lambda type are due to the combined effect of rectilinear and to some extent torsional shear against some powerful resistance on the lateral side. The greater the amount of twisting, the more arcuate are the folds of the subordinate limb. The varietal forms depend upon the relative position of the region that undergoes the shearing movement and the region that offers the resistance. If the resistance comes from the right, then the normal type will result; if it comes from the left or left-lower side, the reversed type will appear; and finally if it comes from the right-lower side, then the resulting lambda will be inverted.

(*g*) *Geniculate Type*.—As in the epsilon type, the geniculate type also possesses two wings, each of which comprises a succession of similarly disposed folds or thrusts. The two wings come into abrupt contact, and often form a sharp angle or a geniculated curve. In other words, the apex of the system is not formed by a gradual bending of the wings so as to describe a smooth curve, but represents the junction of two sets of independent structural axes. The wings may be slightly curved with their convex front facing the concave side of the whole system.

Although this type exhibits some apparent similarity to the epsilon type, it is sharply distinguished from the latter not only by the peculiar arrangement of the wings and their juxtaposition at the apex, but by the absence of a central ridge, or axis, on the concave side of the geniculated curve. This latter fact affords an infallible distinction between the two types.

In Eastern Asia we have not yet found any classical example of this type; but it is known to have developed in its ideal form around the north-western corner of India. In his recent memoir, Wadia[1] describes the structure of Poonch-Narh area as being characterized by two sets of curved axes meeting along the Jhelum Valley. The eastern set follows the strike of the Pir Panjal, viz. S.E., and the western set follows the zone of Eocene of Hazara, viz. S.W. These two sets of strikes are each observed on one side of the Jhelum after it passes Muzaffarabad, where the angle between the two strikes is as acute as "something like 40°". Southward, the inflection gradually becomes broader. In the Piedmont belt around Mirpur, the angle is increased to about 120°. Further south in the Kharian Hills the influence of this syntaxial indentation almost completely disappears. Here we must note that throughout this broad zone between Muzaffarabad and Mangla, nearly 100 miles wide, we find no feature that corresponds to the axis of the epsilon system. This fact alone assures us that we are dealing with a geniculate type of structure which has nothing to do with the epsilon type.

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[1] D. N. Wadia, "The Geology of Poonch State (Kashmir) and Adjacent Portions of the Punjab": *Mem. Geol. Surv., India*, vol. li, pt. ii, 1928, pp. 198–201, 292–362.

More examples of this type occur in Central Asia. They cannot, however, be discussed here because of limitation of space.

EXPERIMENT VII. (Plate XVI, Fig. 1.)

Produce two large-sized epsilon structures as in Experiment V side by side so that the left wing of one system comes into contact with the right wing of the other. In the conjoint wings we shall see the essential features of the geniculate type of structure. This experiment shows that the genicula are produced through two independent but simultaneous movements which came from the exterior of the wings, but not from the interior of the system. The apex therefore points towards the side where the movement came from.

V. MECHANISM OF TECTONIC MOVEMENTS.

Geologists are apt to be under the illusion that contemporaneous movements in a region of close tectonic connection came from one definite direction. This is by no means always true. The analysis of structural types in Eastern Asia and elsewhere shows that it is the nature of the tectonic unit that determines the direction of movement in a region not only in a given period of disturbance but throughout different periods of movement so long as the unit persists. In Eastern Asia, and particularly in China, it is a commonplace to find Archaean rocks with their plane of schistosity striking in the same direction as the youngest disturbed strata. The underlying reason must be two-fold : firstly, the disturbing forces came from the same source throughout geological time ; and secondly, the relative configuration of the tectonic units has not altered to any appreciable extent. On the other hand, if two neighbouring regions each belong to different tectonic units, their movements may be widely different even in the same period of orogeny. It is usually due to the derangement or destruction of the pre-existing units, or the formation of new units through the fragmentation of the continent in the course of time, that superimposed movements of different directions are produced. Europe, perhaps, offers the best example of such regions.

Viewing Eastern Asia in its broader tectonic outline throughout space and time, we are fortunately not confronted with the difficulty of retracing the extinct tectonic units. We know that certain features have evolved since the Palaeozoic Era, but they have been produced through similar, if not exactly the same, mechanical processes that were engaged to bring out the pre-Palaeozoic structures. The structures of the Amphitheatre of Irkutsk and its adjoining country, as well as of the east and west zones, testify to this general statement. Rid of this difficulty, we need not attach so much importance as one might at first imagine to the chronology of the various tectonic movements for determining the general mechanism of Eastern Asiatic movements.

The presence in Eastern Asia of five east and west zones, of which at least three are known to have been in existence since very ancient geological time, indicates that the whole region has been again and again subjected to longitudinal compression. The structures of these highly disturbed zones alone cannot, however, afford any decisive evidence as to whether the region as a whole or its several blocks separated by those zones moved northward or southward. An *a priori* judgment based on the direction of overthrust proves to be untenable. A very close relation is found between the E.–W. zones of compression and the N.N.E. ranges such as the Aldanski, the Great Khingan and the Sikhota-alin, the Taihang, and the eastern border of the Kweichow Plateau, as well as the bordering geosynclines and their complementary island arcs. Attention has been already called to the fact that the indentations of the Eastern Asiatic island chain occur exactly at the points where the E.–W. zones ought if prolonged, or actually do, emerge on the continental border, and that the individual arcs as well as their related inland ranges are not uniformly curved, but are bent to a greater extent in their southern part. The genesis of these features not only requires a powerful compression between Eastern Asia and the Pacific, but also a relative horizontal displacement to the south on the part of the continent, or to the north on the part of the Pacific floor. Had it not been for the existence of the several E.–W. zones, the border features would have been more or less rectilinear and the individual arc would not have resulted. The present configuration of Eastern Asia affords therefore a highly suggestive indication that horizontal displacement occurred on the part of the continent; and that because the direction of the horizontal movement is oblique to the continental border there has been a lateral compression normal to the border of the continental mass.

As already said, the above is but an argument in favour of the inference that Eastern Asia as a whole moved southward. The more reliable criteria are to be found in the structural types. All along the island arcs from Kamchatka and the Kuriles down to the Riukiu Islands and again from the Marianne to the Pelew we find a succession of the xi structures mostly of the convergent type. As already mentioned, in each of these island arcs there are probably two groups of convergent xi lines. The north-eastern, or the dominant group, has its anterior end pointing to the S.W., while the south-western, or the subsidiary group, has its anterior end pointing to the east or E.N.E. These facts demonstrate at once that there has been a strong tendency for the bordering tracts of Eastern Asia to shift southward, with the necessary consequence of giving rise to a lateral pressure against the Pacific. It is the resultant of these sets of forces, which must be directed toward S.S.E., that has been responsible for the development of the asymmetrical arrangement of the two groups of convergent xi lines in each of the bordering arcs. In the eastern part of the main land of Eastern Asia structural axes with the Sinoid trend, viz. N.E., spread from Eastern Siberia to the extreme south of China. On the other hand, north-westerly axes dominate the country between East Sayan and the Tibetan massif. These two sets of xi lines cannot be produced unless Eastern Asia, at least that part of Eastern Asia which is covered by the Sinoid and Sayan types of structures, has effected a horizontal shear towards the south against the resistance of the Pacific on the one side and that of the Tibetan massif on the other.

To this there is to be added the evidence, even more cogent, afforded by the epsilon structures. In Siberia there is that great epsilon system headed by the Amphitheatre of Irkutsk. In North China a second epsilon system occurs, embodying the Nanshan-Shansi-Liupanshan Ranges. A third epsilon system occurs in South-Western China, embracing the Yunnan Arc and the region immediately to the north of it. These epsilons cover large areas with their apices all pointing to the south. Only a small one of reflex type, namely, that developed in the Nanking Hills, has its apex pointing to the north. From these features it may be gathered that Eastern Asia has locally undergone some horizontal movements. The sections are divided by the west and east zones of Tannu-Kentei, Inshan, Tsinling, and Nanling. Extending across or between these zones, there are three large epsilons. The first epsilon is delimited on the south by the Tannu-Khanghai-Kentei, the second encompasses the full width of the section between the Inshan and the Tsinling, and the third lies between the zone of the Tsinling and that of the Nanling. The presence of these epsilons shows that each section did not move uniformly, but effected some differential or shearing movements against lateral resistances on the east and the west. The eastern resistance is obviously offered by the floor of the Pacific, and the western is to be traced directly or indirectly to the Tibetan massif. While the several sections were more or less independently effecting a southward shear, the relatively sheltered areas, so to speak, such as the Nanking-Chienkiang district, may have remained as a stumbling-block. An apparent counter-movement would then result. The fact that the Nanking-Chienkiang epsilon has its apex pointing to the north is, therefore, a natural result of such a southerly differential movement (cf. Pl. XV, Fig. 2, p. 9).

Then there are the nu types of structure developed in South China, Indo-China, and Borneo. Experimental evidence shows that these were produced by torsional shear. The region involved must have undergone a horizontal twisting movement. As the distribution of the nu types has not yet been fully mapped out, we cannot, for the present, determine the axial region or regions around which the twisting movement took place. One thing is, however, sure, namely, the fact that the several examples of the nu type already described converge to show a clockwise twisting of south-eastern Asia.

The evidence furnished by the nu types is corroborated by the normal lambda type developed in the Philippine Islands and the reversed lambda type in Sumatra and Java. Further concurrent evidence is found in the eta type of structure as developed on the south-eastern border of the Tibetan massif around the eastern terminus of the Himalaya. This last-named group of evidence not only affords a reassuring confirmation of a clockwise torsional shear in south-eastern Asia, but indicates very plainly that the axial region of the torsional shear lies somewhere in the Tibetan massif. Although local axes of twisting movement may exist within the vast area of Eastern Asia, the principal one must be found in the last-named tract. This enables us to conclude that south-eastern Asia as a whole rotated clockwise around the southern part of Tibet, being more or less checked by the Indian block on the west.

(To be continued.)

REVIEWS.

The Fossil Flora of the Upper Karroo Beds. By A. L. du Toit. *Ann. S. Afr. Mus.*, XXII, 1927, pp. 289–420, pls. xvi–xxxii, 24 text-figures.

CURRENT theories of continental displacement have stimulated interest in those regional floras of past times, such as the Triasso-Rhaetic *Thinnfeldia* flora of the southern hemisphere, which seem definitely to demand land connections of one sort or another. Close floral resemblances may be susceptible of more than one explanation, but no finality is likely to be reached until the contemporaneous plant assemblages have been carefully revised and studied on modern lines. For the Upper Karroo beds of South Africa this work has now been admirably accomplished by Dr. du Toit. In addition to giving detailed descriptions of some seventy or more species, he analyses a series of comparable floras from other parts of the world, and comes to some important conclusions as to the age and correlation of the Upper Karroo series. Plants are most abundant in the Molteno beds, whose age Dr. du Toit considers to be Upper Triassic (Keuper). Floras of this type have in the past been loosely described as Rhaetic, but exact determinations of the age have rarely been attempted. The reference of the Molteno beds to the Upper Triassic is partly dependent on the conclusion, which rests to some extent on reptilian evidence, that the underlying Upper Beaufort beds are Lower, or at the latest Middle, Keuper. The rather scanty flora is quite consistent with such a determination.

The supposed uniformity of "Rhaetic" floras all over the globe has probably been exaggerated in the past, though Dr. du Toit thinks that further collecting will emphasize the resemblance of the Beaufort flora to that of the European Trias. Nevertheless he mentions several characteristic northern genera which have not yet been found in South Africa. He considers that the Eurasian Rhaetic elements probably originated in Gondwanaland, and therefore made an earlier appearance there than in the northern hemisphere. The Permian elements in the Molteno flora, on the other hand, are presumed to be mainly of northern origin, though there are some survivals from the local *Glossopteris* flora. The genus *Glossopteris* itself is recorded by the author from the Middle Molteno Beds—apparently its latest known survival; the only other record, by Arber (*Glossopteris Flora*, 1905, p. 61) of a specimen of *G. browniana* from the Molteno beds near Cyfergat, is, however, an unaccountable error, as the specimen in question (in the Geological Department of the British Museum) is clearly registered as from Bedford, and is presumably of Beaufort age.

A word must be said about the illustrations. Dr. du Toit has expressly avoided photographs, since they are frequently very unsatisfactory when, as in this case, the specimens are impressions on dark shale. If all drawings of fossil plants were as clear and careful as those with which the author has embellished this memoir, the path of the palaeobotanist would be considerably easier.

W. N. E.

MURBY'S PROFILE SHEETS. Thomas Murby & Co., London.

THESE sheets will be found very useful for drawing sections of 6 inch maps. The spacing of the lines is on the scale of 100 ft. intervals. The sheets are printed in a pale grey-blue on good paper. Each sheet is made for a 12 inch section. The only possible criticism is as to the price, which is at the rate of ten sheets for 6*d*.

DIE ENTSTEHUNG DER MEDITERRAN-ROTERDEN (TERRA ROSSA). By A. REIFENBERG. Extract from Kolloidchemische Beihefte, Leipzig, pp. iv + 93. Dresden and Leipzig, Theodor Steinkopf, 1929.

THE Terra Rossa of the Mediterranean region is the characteristic residual product of the weathering of limestones under the special conditions of the Mediterranean type of climate, with its dry summer and wet winter. The material is analogous to laterites and bauxites, though always very much richer in silica: other notable features are comparative abundance of soluble salts and extremely low humus-content. The author of this memoir has worked mainly in Palestine, and admits quite frankly that he has not seen any tropical lateritic deposits. There is nothing particularly new in the first, more geological section of the memoir. The second part is mainly taken up by a detailed discussion of the formation of terra rossa in the light of colloid chemistry, a matter which is scarcely geological, though of much interest to soil students. In the bibliography of 146 items we have not observed any mention of the fine book on *Bauxite*, by Dr. Cyril S. Fox, published in 1927, in which there are many references to the close relation of terra rossa to bauxite and laterite.

THE PRESERVATION OF PYRITISED AND OTHER FOSSILS. By E. G. RADLEY, F.C.S. *The Naturalist* for April, May, and June, 1929.

IT has always been a trouble to preserve fossils from decomposition. In this paper the author describes his experiments upon the causes and prevention of the destruction. Many of the covering materials which are in general use, together with others which would appear to have a greater prospect of resisting atmospheric conditions, were employed, and it was found that nitro-cellulose provides the most resistant surface. Nitro-cellulose is used for water-proofing aeroplane wings, under the name of "dope"; while the same material, in a dilute form, is often employed to protect metallic surfaces. For this latter purpose, the solution of nitro-cellulose is supplied under such names as "invisible lacquers", etc. The protective powers of the various media were tested by very drastic methods, which were calculated to represent such changes as might be expected to occur over an indefinite but very considerable number of years. The author urges the advisability of thoroughly washing and drying the fossils before coating them with nitro-cellulose.

RHYTHMISCHE PHÄNOMENE DER ERDOBERFLÄCHE. By HENNING KAUFMANN. vi + 348 pp., with 15 text-figures. Braunschweig: Vieweg und Sohn, 1929. 14 marks.

THE "rhythmic phenomena" of the author of this book include a variety of forms upon the earth's surface, which differ greatly in magnitude and character but agree in showing some kind of rhythm or repetition. Amongst them are sand-ripples and sand-dunes, waves, the branching tributaries of a stream, maeanders, nieves penitentes, etc. The author's contention is that they are all produced by the relative movement of two different media in contact with each other, and are due to the disturbance at the zone of contact. The reader will naturally look for some explanation of the reason why this disturbance should become rhythmic, but he will not find it. The author never attempts any rigid proof and his pages are free from mathematical symbols. He contents himself with vague references to external and internal friction which the most docile reader will scarcely find satisfying. Even in the particular cases which are discussed at length it is difficult to arrive at anything definite. The reader after wading through somewhat sarcastic discussions of other people's theories and waiting hopefully for the true one is often surprised to find that the author is under the impression that he has already conclusively proved it.

But the book is not without its use. The author is not himself an observer, but he has collected both the observations and the theories of others. Since the subjects dealt with have attracted the attention of physicists, engineers, geologists, geographers and others the material is very widely scattered and the author has performed a useful service by bringing it together. A very good bibilography appended to the book makes it easy to find any of the papers referred to in the text.

P. L.

REPORTS AND PROCEEDINGS.

Geologists' Association.

" Chalk Zones in the Neighbourhood of Shoreham, Brighton, and Newhaven, Sussex." By Christopher T. A. Gaster, F.G.S. (Weald Research Committee Communication.)

The district described, the coastal portion of which lies between Shoreham and Seaford, extends for about 15 miles and is a continuation eastwards from the area dealt with in the paper on the Worthing Chalk. The inland extension is about 2½ miles at Shoreham, widening to 6 miles at Bishopstone, west of Seaford. The western boundary is drained by the river Adur and the eastern by the River Ouse. Anticlinal and synclinal folds are present. The extension of the zone of *Offaster pilula* to include the *Hagenowia* horizon is fully maintained and an additional *Echinocorys* belt in which large forms dominate has been defined. The bed near the base of the *M. coranguinum* zone, in which *Trochiliopora* is common, is recorded. All zones ranging from *S. varians* to *A. quadratus* are present and are represented by over 130 exposures in pits and sections.

" Some Features of Lamprophyres, near Sedbergh, Yorkshire." By H. G. Smith, B.Sc., A.R.C.S., F.G.S.

The rocks examined are minettes, containing pseudomorphs after pyroxene and olivine. Some nests, rich in orthoclase, occur, but this material is also found as irregular streaks. Xenolithic material is represented by garnet, kyanite, and possibly sillimanite and andalusite. There are also fragments of felspathic grits, in which the quartz is partly converted to tridymite.

The view expressed is that the roof of a major basic intrusion was frozen before it could incorporate the foreign material; gravity differentiation resulted in the accumulation under this of a light fraction rich in volatiles; reaction between the two developed the lamprophyre either before or after injection into the fissures of the overlying rocks. The nests of orthoclase are considered to be portions of the light differentiate entangled with the roof material.

GLASGOW GEOLOGICAL SOCIETY.

14*th February*, 1929.

"*Trinucleus* in the Girvan Area." By J. L. Begg.

The genus *Trinucleus* belongs to middle and upper Ordovician horizons, and is reported from the Balcletchie group of Dow Hill, the Whitehouse group of Whitehouse Bay and Shalloch Mill, and from Drummock and South Thraive.

Two species occur, *Trinucleus bucklandi*, Barrande (Upper Bala), and *T. sub-radiatus*, Reed; the paper is concerned with the latter. A head-shield was described in Dr. F. R. Cowper Reed's *Lower Palaeozoic Trilobites of the Girvan Area* (1906). Specimens have now been found in which the thoracic segments and pygidium are present. It is found that the nuchal spine is merely the base of the actual spine, which extends to and covers the fourth thoracic segment. The thorax, considerably narrower than the head-shield, has six segments; axis convex, prominent, about one-fourth width of the thorax; axial rings pitted; pleurae straight, horizontal, with broad median, longitudinal groove, bordered by well rounded, elevated margins; the ends of the pleurae are pointed and bent backwards. The thorax conforms to the generic type; specific differentiation takes place in the head-shield and pygidium. Pygidium: marginate with narrow rounded border; posteriorly truncated; narrows gently backwards; postero-lateral angles rounded; five times as broad as long; axis convex, conical, about one-fourth breadth of pygidium, extending to the posterior extremity, deeply grooved; the rings are more numerous than the ribs in the lateral areas. These are three in number, and directed obliquely backwards.

This increase in the number of axial rings posteriorly without corresponding increase of ribs on the lateral lobes of the pygidium is a feature common to many trilobites. The ribs of the pygidium have an increasing bend posteriorly and so occupy more space at their junction with the axial segments. If the ribs and axial rings are to remain equal in number the latter must increase in size and as the elevated ring is stronger than the furrow this will diminish the flexibility of the tail-piece. The number of rings is increased for this reason by subdivision of those near the posterior border. It may be objected that many stocks have the pygidium in a state of morphological fusion but this argument fails unless it implies complete rigidity. If the chitinous carapace had a degree of flexibility increase of the axial furrows would supplement this quality ; the increase of number in the rings may have developed before fusion.

" The Pre-Glacial Valleys of the Clyde and its Tributaries." By M. Macgregor, B.Sc.

The old pre-glacial courses of the Clyde and its tributaries are as a rule less gorge-like and deeper than the present valleys and their accurate delimitation is of very great importance where coals are being worked in their vicinity at a shallow depth. Special attention was drawn in this paper to the relation of the old Kelvin Valley to the valleys of the Clyde and the other tributaries of the latter. The Kelvin Valley is over 100 feet deeper than the old Clyde channel, and this super-deepening has been attributed to glacial erosion. The suggestion was put forward that in the pre-glacial Clyde-Kelvin channels two different drainage systems are represented. The deep Kelvin hollow is possibly part of an early drainage system developed when the Clyde below Dumbarton became an obsequent river. At a later stage the Clyde became the important stream cutting backwards and extending its drainage area, while the Kelvin was merely a sluggish stream winding over its old alluvial flats.

" Account of a Gravitational Survey over part of the buried Kelvin Valley, near Drumry, Glasgow." By Dr. J. Phemister.

Dr. Phemister gave a summary of the results obtained by a gravitational survey by means of the Eötvös Torsion Balance. The survey was carried out in the district round Drumry, 7 miles west-north-west of Glasgow. In this area borings have shown the existence of the pre-glacial channel of the River Kelvin, and from this evidence it has been thought that the pre-glacial Kelvin forked at Drumry, one branch continuing westwards, the other branch passing southward to meet the Clyde. By means of the balance the western bank of the south trending channel was traced for nearly a mile, its slope was estimated as one in six and the thickness of the drift at the top of the slope was calculated and found to agree well with the boring evidence. The gravitational results, however, were contrary to the hypothesis of a westward branch of the old valley ; they indicate that the ancient river valley, running westward from Bearsden, takes a right-angle bend at Drumry and turns southward towards the Clyde. The detailed account of the survey is published in the *Transactions of the Royal Society of Edinburgh*, vol. lvi, pt. i, 1929.

11*th April*, 1929.

"Glaucophane and Allied Minerals in Scottish Rocks." By Dr. W. Mackie.

The examination of forty specimens of Torridonian rocks showed the presence of one possible glaucophane in association with twenty other heavy mineral species. It was ovoid in shape, pleochroic from violet to a fainter violet, and extinguished at a small angle with the longer axis of the oval. The Torridonian has been derived, at least in part, from the Moine, and a possible source of this (?) glaucophane is a sericite schist from between Loch Hope and Ben Hope in Sutherland, which contains a soda-amphibole, pleochroic from blue to muddy-yellow or green and extinguishing at 3 degrees. At St. Fillans, Perthshire, in the Ben Ledi Grits, a blue platy mineral occurs. Crushing produces straight-edged fragments, but the edges rarely correspond with the cleavage lines of the amphibole, so that the extinction angle is hard to determine, but angles of 20 degrees and over have been observed. The pleochroism is from yellow to green and there is little doubt that the mineral is not glaucophane. Similar fragments possibly derived from this locus, are found in Upper Old Red residues from the Heads of Ayr, and in Carboniferous residues from Kilsyth, Auchenlea and Sanquhar. The Llandeilian and Caradocian greywackes of Bail Hill (Sanquhar), Leadhills, and especially those about 3 miles south-west of Sanquhar on the road to Thornhill are rich in glaucophane. It occurs as scales extinguishing at 3 degrees, but as often showing straight extinction. The pleochroism is from indigo-blue to violet, or to yellow or colourless. This is believed to be true glaucophane.

(*a*) Note on the Geology of South Bute.
(*b*) Note on a Dyke, Loch Skiport, South Usit.
(*c*) Rocks from the Flannan Islands.
By W. J. McCallien, B.Sc.

(*a*) A diagrammatic sketch drawn from a point a short distance south of the Hawk's Nib, and looking north was used to illustrate the unconformity between the rocks of the Upper Old Red Sandstone and the Calciferous Sandstone Series. A hitherto unrecorded dyke of trachyte or mugearite on the shore at the columnar sandstone, 400 yards south of Kilchattan Bay Pier was also described and references were made to other igneous phenomena.

(*b*) An unrecorded dyke of olivine-dolerite was described from the western shore of Little Kettle Pool, Loch Skiport, South Uist.

(*c*) A collection of seventeen rocks from the Flannan Islands, 15 miles north of west of Gallon Head, Lewis, was exhibited. The specimens show that this group of islands is composed of rocks similar to those of the Long Island itself. The gneiss seems to represent the more basic members of the suite—hornblende- and biotite-rocks. Into these is intruded a varied series of pegmatites and graphic granites. Traversing the island is a basaltic dyke, which has been eroded to form a small gully. The specimens were collected by Mr. Neil Murray, Assistant Lightkeeper at the Flannan Islands.

"Heavy Residues of the Calciferous Sandstone Series of the Glasgow District." By B. Hilton Barrett, M.A., B.Sc., Carnegie Teaching Fellow, Glasgow University.

The Calciferous rocks of the district are divided into Upper and Lower Sediments by the lavas of the Clyde Plateau. The residues from the lower sediments vary considerably. In specimens from near Helensburgh zircon and apatite are sparse, tourmaline rare and garnet very abundant; at Dumbarton, zircon is still sparse but apatite is very abundant, while garnet and rutile, after testing several specimens, were proved to be entirely absent. Near Kilsyth, one specimen showed the same association as at Dumbarton, yet the bed immediately above, and just below the lavas, contained abundant zircons and garnets with little apatite. In addition, some hypersthene is present. In the Ballagan Beds zircon, apatite, garnet, tourmaline and monazite are present.

In the upper sediments the residues from the lavas to the horizon of the Blackbyre Limestone contain only zircon, rutile and tourmaline, but above the limestone apatite and monazite are present in addition. The only occurrence of garnet above the lavas which is known is in the exposures of the Craigmaddie Conglomerate on the Douglas Muir north of Clydebank. Associated with it is some (?) staurolite. Such minerals as kyanite and andalusite have not been observed. One piece of fluorspar was seen in a residue from the lower part of the upper sediments.

GEOLOGICAL SOCIETY OF LONDON.

The following is a list of the foreign members elected on 26th June, 1929:—

Professor Charles Schuchert, of Yale University, Newhaven, Connecticut; Professor Pierre Termier, Directeur des Services de la Carte Géologique de France, Paris; Dr. Edward Oscar Ulrich, U.S. Geological Survey, Washington, D.C., U.S.A.; Dr. Thomas Wayland Vaughan, Director of the Scripps Institution of Oceanography, University of California.

Foreign Correspondents were also elected as follows:—

Professor Othenio Abel, of Vienna; Dr. Clarence N. Fenner, of Washington, D.C., U.S.A.; Professor Olaf Holtedahl, of Oslo, Norway; Dr. Rudolf Staub, of Berne, Switzerland; Dr. V. K. Ting, of Peking, China; Professor Carl Wiman, of Uppsala, Sweden.